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POLLINATION AND BLOOMING HABITS OF THE PERSIAN WALNUT IN CALIFORNIA

By MILO N. WOOD

Pomologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry

CONTENTS

INTRODUCTION

Most of the Persian ("English") walnuts produced commercially in the United States are grown on the Pacific coast. California produces about 95 percent of the total crop, while Oregon and Washington have a small but increasing walnut industry. The total area in walnuts in California in 1929 was 127,485 acres, of which 87,564 acres were bearing trees and 39,921 not yet in bearing; the acreage in Washington and Oregon was approximately 18,000, slightly over half of it being young trees not yet in bearing. The average annual production in California for the 10-year period 1918–27 was 52,320,000 pounds, the minimum being 30,000,000 pounds and the maximum 102,000,000 pounds per year. There is considerable variation from year to year in the size of the crop produced. Sometimes a light crop is traceable to some such simple and obvious cause as heavy frosts affecting large areas during the blooming season, but more often the causes for crop failure are not easy to discover. Even in years when the average yield is high, growers are sometimes baffled by the failure of the individual orchards or groups of orchards to bear.

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It has long been suspected that a light set of nuts, as well as other characteristic walnut troubles, including the premature dropping of the pistils, failure of the kernels to fill out, "off-shaped" nuts, and defective shells, may be related closely to pollination. Van Deman (*13*),[1] in Bailey's Cyclopedia of Horticulture, wrote:

> On the Pacific coast the Persian walnut is a great success * * *. True enough there are some failures, but they are mostly due to lack of proper pollination, a matter which can and will soon be generally understood and overcome.

In the absence of scientific data there has been great diversity in the opinions and practices of orchardists. Many have planted single varieties in large blocks in the belief that self-pollination is adequate. Some have attempted to insure cross-pollination by planting rows of black walnuts on the outskirts of their orchards. Other growers have planted several varieties, maintaining that cross-pollination improves the yield, the varieties being selected necessarily at random without accurate knowledge of blooming habits or pollination characteristics. One so-called variety which has been a great favorite in California, the Santa Barbara, is not a single variety but merely a seedling type.

It should not be supposed that pollination is the only factor that may affect the setting and filling of walnuts. Water shortage, severe leaf injury or lack of foliage development, and poor nutritional conditions, such as an insufficient supply of nitrogen, must also be taken into account as possible causes of light crops. The fact remains, however, that pollination as a factor affecting walnut production has not received adequate scientific attention heretofore.

In an effort to solve the problem of the exact relation of pollination to crop production, experiments were begun on a small scale in 1920 and were continued with increasing emphasis each season until 1929. While all phases of the subject have not been dealt with fully as yet, certain facts have been ascertained which throw light upon the problem and which, it is hoped, will pave the way for a more complete solution. This bulletin is, therefore, a report of findings to 1929 thought sufficiently significant to be of value to growers.

The experiments followed three main lines: (1) The leading varieties and a few of the unusual varieties were tested to ascertain whether they were self-fertile or self-sterile, whether they were interfertile or intersterile, and whether they differed in degree of self-fertility or interfertility. (2) Detailed studies were made of each of the varieties to ascertain the relative time of the blooming of the pistillate and staminate flowers and the relation this might have to crop production. (3) Experiments were conducted to determine what relation certain other pollination factors have to nut development and production.

BLOOMING HABITS

A brief consideration of the blooming habits of the walnut is necessary to a clear understanding of pollination problems. The Persian walnut (*Juglans regia* L.), like all other species of the genus Juglans, is monoecious, and bears anemophilous unisexual flowers.

[1] Italic numbers in parentheses refer to Literature Cited, p. 56.

Although both types of flowers (staminate or male blossoms and pistillate or female blossoms) are borne upon the same tree, they are produced upon wood of different age and structure.

The staminate flowers develop from buds formed upon wood of the previous season. The buds remain upon the tree throughout the winter months. Such buds are produced in the leaf axils of the twigs (fig. 1), and ordinarily occur singly, often with a leaf bud just above the axillary flower bud on the twig. In some varieties two or more staminate buds are occasionally found in the leaf axil (fig. 1, *B*). The position of the staminate buds relative to the leaf buds, leaves, and fruit is shown in figure 2.

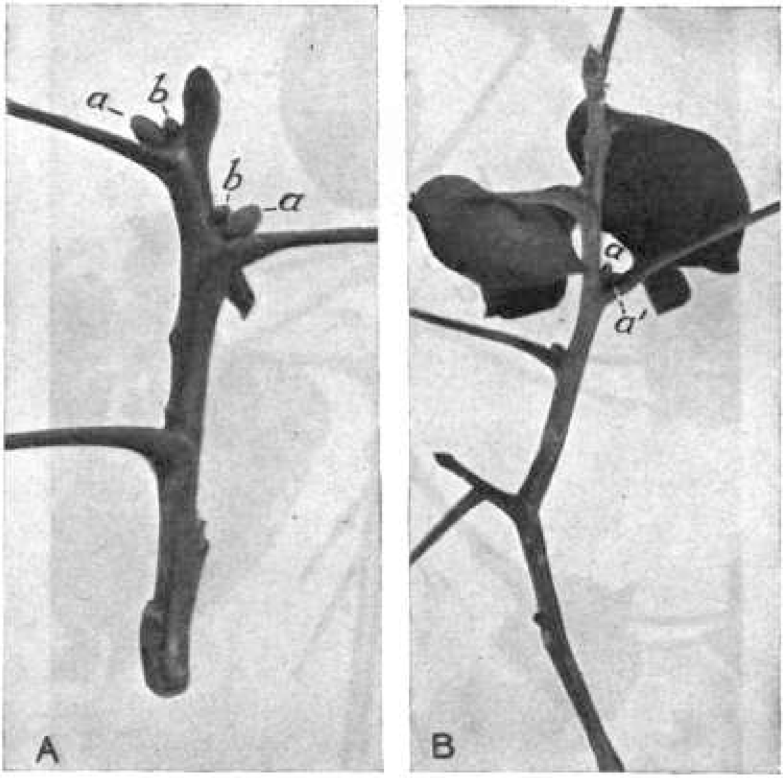

FIGURE 1.—Walnut twigs showing position of staminate flower buds in axils of leaves: *A*, Twig showing axillary catkin buds (*a*) and leaf buds (*b*); *B*, twig showing two catkin buds (*a* and *a* [1]) in axil of the leaf. The buds are formed during the growing season and remain dormant over winter. Frequently leaf buds of the type shown at *A*, *b*, remain dormant season after season.

The pistillate blossoms (fig. 3), on the other hand, are borne terminally on shoots produced during the current season (fig. 4, *b*; also fig. 13, *C*, *c*). The number of pistillate flowers appearing on the tip of each branch varies with the variety, season, and vigor of the shoot. The pistillate flowers are borne upon a rather succulent growth, whereas the staminate flowers are borne upon twigs possessing a more woody structure. Pistillate flowers are produced and develop into nuts in a single season, and do not pass through a dormant season or resting stage as do the staminate buds (figs. 2, 4, and 5). This difference in the types of wood on which pistils and catkins are borne seems to have an important influence upon their behavior, as will be shown later.

The development of the staminate flowers during the blooming time in the spring is interesting. When warm weather comes the short cone-shaped bud enlarges, the bud scales open, and the spike bearing the immature flowers elongates. It points upward at first, but with its continued elongation and the enlargement of the

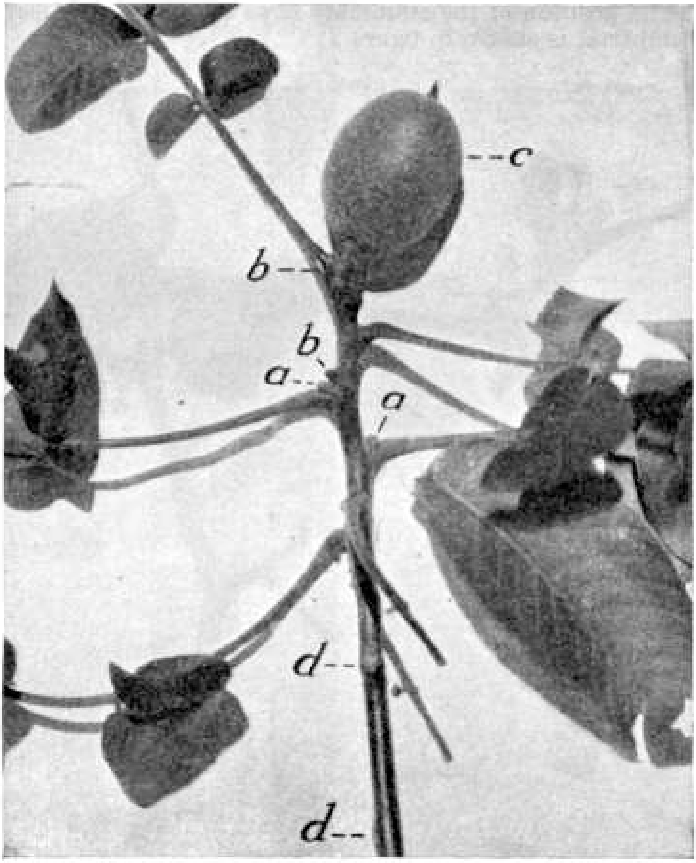

FIGURE 2.—Walnut twig showing relative position of catkin buds, leaf buds, leaves, and nut: *a*, Catkin buds; *b*, leaf buds; *c*, nut; *d*, leaf scars.

individual flowers it finally becomes pendent. In all varieties the staminate catkins are pendent a considerable time before the pollen grains are shed. The flowers in the pendant catkins are in an inverted position, the stamens hanging downward. As the anthers in the flowers dehisce, much of the pollen falls, if there is no wind, into the cup-shaped depressions upon the backs of the flowers below, as described by Kerner (*7, 1902 ed.*) for the genus Juglans. These depressions are formed by the turning back of the calyxes (fig. 6). Through this peculiarity in the structure of the flowers the pollen is prevented from being scattered upon the ground when the air is still. Later, when winds arise, the pollen is blown out of the cavities in the calyxes and is transported considerable distances. In the common varieties of Persian walnut grown in California the shape of the calyxes varies, so that the efficacy of this natural method of conserving the pollen is greater in some varieties than in others.

Besides the structure of the flowers, three other characteristics of the walnut tend to insure the proper distribution of its pollen: (1) The pollen grains are so small that they can be carried by the wind; (2) a vast number of pollen grains are produced, with the result that much waste may occur without preventing efficient distribution; (3) the catkins on the tree do not all mature at once, but bloom over a considerable period, increasing the probability that at least some of the pollen will be distributed during favorable weather. As the individual flowers in a catkin mature at different times, under some conditions a single catkin may produce pollen for several days.

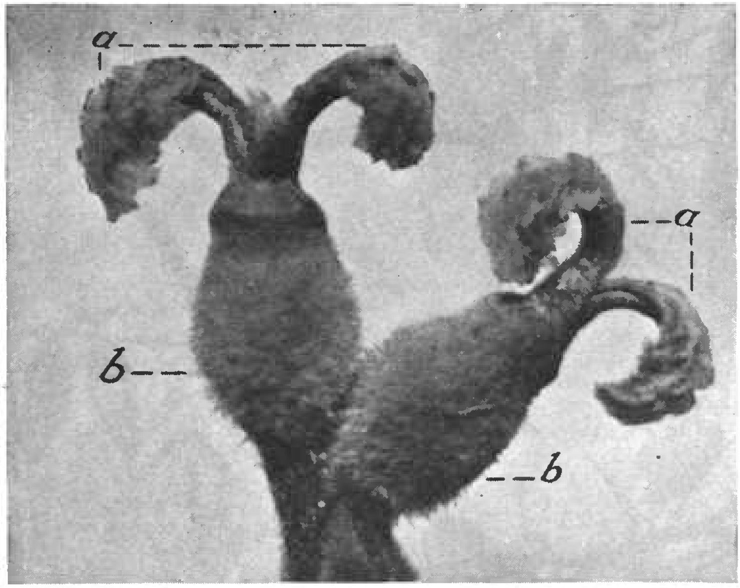

FIGURE 3.—Pistillate flowers of the walnut slightly magnified. *a*, Stigma, which receives and holds the pollen grains; *b*, ovary, which under proper conditions develops into the nut

FERTILITY AND STERILITY

ARTIFICIAL POLLINATION AS A MEANS OF ASCERTAINING WHETHER VARIETIES ARE SELF-STERILE OR INTERSTERILE

In theory the method of determining whether walnut varieties are self-fertile or self-sterile, interfertile or intersterile, is comparatively simple. All that is necessary is to protect the stigmas from receiving pollen by natural means until such time as it is appropriate to apply the desired variety of pollen to them by hand, after which all other pollen must be excluded. In actual practice many difficulties were encountered.

METHODS USED IN ARTIFICIAL POLLINATION

An attempt was made to exclude the pollen from the stigmas by covering the tips of the branches with glassine and manila-paper bags, which were replaced from time to time as necessary. Except in cool seasons, this method was unsatisfactory, because overheating within the bags often occurred and caused the pistils or small nuts to drop.

The most satisfactory covering for the pistils was finally found to be cotton batting, such as comes in rolls for quilt making. Cotton had been previously used by the late Walter Van Fleet, of the United States Department of Agriculture, for excluding pollen in his walnut-

FIGURE 4.—Walnut branch showing manner in which staminate and pistillate flowers are borne. *a*, Catkin which grew from a catkin bud similar to that shown in figure 5, *a*. The catkin bud originated during the previous growing season and remained dormant over winter. The catkin is borne upon wood of last season's growth ("hardwood"). The shoot shown at *x* developed during the current season from a foliage bud similar to that shown in figure 5, *b*, and bears terminally the pistil, *b*. Last year's wood growth leaves off and this year's growth begins at *c*. Leaf scars are shown at *d*.

breeding work. After several methods of applying cotton to walnut pistils had been tried, the following procedure was found to be most satisfactory: A small amount of cotton of just sufficient size to cover the stigma was placed upon it. A large wad of cotton was then wrapped around the tip of the branch so as to envelop completely the end of the twig. The cotton was held in place by small rubber bands. Each pistil cluster was tagged and recorded separately. Owing to the elongation of the tips of the branches as the season advanced, the outer layer of cotton had to be replaced from time to time (every 7 to 10 days). The inner layer of cotton served to prevent any stray pollen from alighting on the stigma while the change was being made. It was essential that the cotton be placed on the twig before any pollen was distributed by the wind. With some varieties and in some districts, as explained later, the staminate flowers or catkins precede the pistils in development. Consequently, it was necessary to cover the tips of the branches very early, in some cases before the pistils formed, in order to be certain that no pollen was deposited where it might later get to the stigmas.

When it was desired to pollinate the stigmas, the cotton was removed, the pollen applied, and the stigma re-covered with fresh cotton. Sometimes the cotton was disarranged through the whipping of the branches in the winds. In some localities birds tore it off for building nests. Where this was the case it was found advisable to cover the cotton on the tips of branches with mosquito netting. When for any reason a pistil became exposed or was injured it was eliminated from the experiments. Cotton was kept on the pistils a considerable time after the stigmas became thoroughly dry and nonreceptive. The pistils appear to develop as satisfactorily under cotton as they do when exposed naturally. The coloring of the stigmas takes place somewhat more slowly, and they do not usually mature quite so rapidly, but otherwise no difference in development is noticeable.

In applying pollen to the stigmas a long-handled camel's-hair brush proved more convenient than the short brushes often used in pollination work, because it afforded comparative ease in avoiding contact with the foliage, which is partly developed at the time the stigmas are receptive.

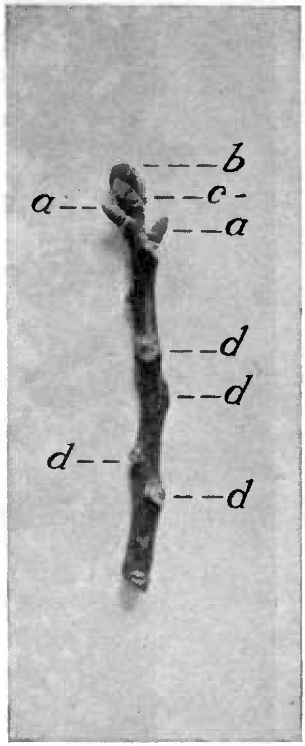

FIGURE 5.—A portion of a walnut twig in the spring just as growth is about to start. *a*, Catkin buds from which will spring catkins similar to the one shown in figure 4, *a*; *b*, leaf or foliage bud which will develop into a shoot, similar to that shown at *x* in figure 4, upon which pistils will be borne terminally. From *c* downward in this figure is wood of the past season's growth, commonly called hardwood. From *c* upward will be the shoot produced during the current season, as shown in figure 4. It is more succulent in growth than that shown below *c*. In both figures 4 and 5, *c* marks the place at which the hardwood of last season's growth ends and the softwood of the present season begins. *d*, Leaf scars.

SELF-FERTILITY AND INTERFERTILITY OF VARIETIES

Experiments were conducted on pistils of 15 varieties of Persian walnut. Pollen from 18 varieties was used,[2] and also pollen from 3 other species, viz, the Hinds walnut (northern California black walnut) (*Juglans hindsi* Rehd.), the California black walnut (southern California black walnut) (*J. californica* S. Wats.), and the Japanese walnut (*J. sieboldiana* Maxim.). Pollinations were made each season from 1920 to 1929, inclusive. Each variety was pollinated by its own pollen and by as many other varieties of pollen as opportunity permitted. The work was performed in as many districts as possible each year.

[2] For a list of the varieties used and a brief description of each, see List of Varieties, p. 50.

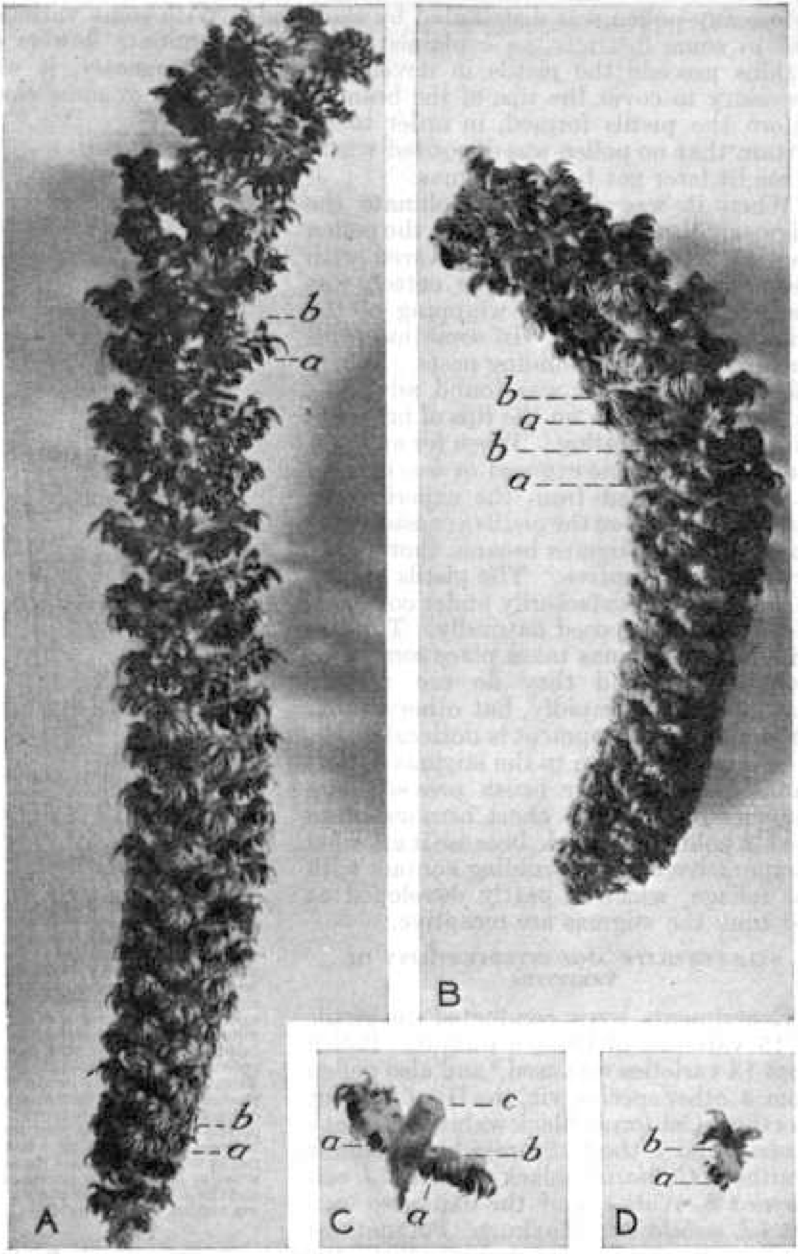

FIGURE 6.—Staminate inflorescence of the walnut. *A*, Catkin with most of its flowers open and shedding pollen. *B*, Catkin with many of its flowers open, but only those at the base and extreme apex are shedding pollen. *C*, Portion of axis of catkin with two staminate flowers attached: *a*, Anthers; *b*, calyx; *c*, axis. *D*, Staminate flower: *a*, Anthers; *b*, calyx. In *C* and *D* note the cup-shaped depressions on the back of the calyx, *b*. Notice that the position of the flowers in the pendent catkin are such that in the absence of wind some of the pollen dropping from the dehiscing anthers falls into the depression upon the back of the calyx of the flower underneath.

Table 1 shows the varieties used, the number of pistils pollinated the total number of matured nuts, and the percentage of nuts matured. The column headed Open pollination shows the results when the varieties listed were pollinated under natural conditions by the wind. In cases involving a small number of pollinated pistils the results are less significant than when a large number were pollinated, but the smaller numbers are included because they have some value. The small numbers in table 1 are due to the fact that in many instances heavy discards were necessary, owing to injury brought by frost, rains, sunburn, aphids, mites, or bacterial blight.[3]

TABLE 1.—*Summary of results of self-pollination, cross-pollination, and open pollination of Persian walnut varieties in California, 1920–1929*

Results when pollen of the indicated variety or species was applied

Variety or species of pistils	Concord			El Monte			Ehrhardt			Eureka		
	Pistils pollinated	Pistils maturing nuts	Nuts matured	Pistils pollinated	Pistils maturing nuts	Nuts matured	Pistils pollinated	Pistils maturing nuts	Nuts matured	Pistils pollinated	Pistils maturing nuts	Nuts matured
	Number	*Number*	*Pct.*	*Number*	*Number*	*Pct.*	*Number*	*Number*	*Pct.*	*Number*	*Number*	*Pct.*
Concord	2, 661	1, 380	51. 8	1, 360	691	50. 8				370	150	40. 5
El Monte				3, 040	553	18. 2				310	120	38. 7
Eureka	[1] 460	55	11. 9	[1] 400	200	50. 0				17, 840	7, 872	44. 1
Golden Nugget				620	51	8. 2				[1] 250	110	44. 0
Franquette										4, 000	1, 215	30. 3
San Jose (Wiltz Mayette, San Jose Mayette)										[1] 1, 100	317	28. 8
XXX Mayette										[1] 410	150	36. 6
Payne	3, 099	716	23. 1	2, 880	1, 524	52. 9				5, 733	2, 492	43. 5
Placentia	[1] 180	110	61. 1	[1] 480	320	66. 6	[1] 275	61	22. 2	[1] 300	269	89. 7
Santa Barbara				[1] 190	10	5. 3						

Variety or species of pistils	Golden Nugget			Franquette			Mayette (Grenoble)			San Jose		
Concord	522	261	50				503	203	40. 3	[1] 90	50	55. 6
El Monte	810	166	20. 5									
Eureka							[1] 70	10	14. 3	[1] 210	10	4. 8
Golden Nugget	985	322	32. 7				[1] 54	44	81. 5			
Franquette	[1]3, 130	610	19. 5	14, 024	4, 311	30. 7	1, 200	400	33. 3	12, 729	3, 745	29. 4
Mayette (Grenoble)							440	289	65. 7			
San Jose				10, 039	3, 092	30. 8				12, 642	4, 389	34. 7
XXX Mayette				100	61	61. 0						
Payne	[1]1, 040	92	8. 8				9, 270	3, 370	36. 3	11, 660	3, 922	33. 6
Kaghazi (Persian)												
Placentia							[1] 444	331	74. 5	4, 187	1, 498	35. 7

Variety or species of pistils	XXX Mayette			Payne			Kaghazi (Persian)			Placentia		
Concord				741	261	35. 2						
El Monte				800	181	22. 6						
Eureka				[1]1, 700	799	47. 0						
Golden Nugget				834	282	33. 8						
Franquette	1, 220	664	54. 5	1, 280	320	25. 0						
San Jose	[1]1, 400	525	37. 5	[1]1, 000	310	31. 0						
XXX Mayette	[1] 590	180	30. 5									
Payne				26, 924	7, 311	27. 2				4, 550	1, 141	25. 1
Kaghazi (Persian)							[1] 670	284	42. 4			
Placentia				[1]2, 320	800	34. 5	[1] 280	221	78. 9	[1] 5, 315	2, 612	49. 1
Santa Barbara				690	162	23. 5				[1] 839	61	7. 3

[1] Pollinations made over a period less than 5 years; other pollinations performed for 5 years or longer.
[3] In 1 year in a certain locality 87 percent of the nuts formed in the Payne variety were injured by blight.

TABLE 1.—*Summary of results of self-pollination, cross-pollination, and open pollination for Persian walnut varieties in California, 1920–1929*—Con.

Variety or species of pistils	Results when pollen of the indicated variety or species was applied											
	Pride of Ventura			Praeparturiens			Santa Rosa			Santa Barbara		
	Pistils pollinated	Pistils maturing nuts	Nuts matured	Pistils pollinated	Pistils maturing nuts	Nuts matured	Pistils pollinated	Pistils maturing nuts	Nuts matured	Pistils pollinated	Pistils maturing nuts	Nuts matured
	Number	*Number*	*Pct.*	*Number*	*Number*	*Pct.*	*Number*	*Number*	*Pct.*	*Number*	*Number*	*Pct.*
Concord										380	141	37.1
El Monte							300	120	40	[1] 190	11	5.8
Payne				[1] 2,148	441	20.5				[1] 3,159	552	17.5
Placentia										[1] 330	270	81.8
Pride of Ventura	[1] 850	80	9.4									
Praeparturiens				[1] 1,180	342	28.9						
Santa Barbara										530	110	20.8
	Wasson			Willson			Hinds			California black		
San Jose							[1] 2,530	981	38.8			
Placentia	[1] 2,539	740	29.1	[1] 2,044	512	25.0	[1] 2,950	1,140	38.6	[1] 230	190	82.6
Santa Barbara				760	200	26.3						
Willson				[1] 890	381	42.8						
							Japanese			Open pollination		
Concord										4,682	1,421	30.4
El Monte										1,871	870	46.5
Eureka										15,238	5,696	37.4
Golden Nugget										1,171	280	23.9
Franquette										18,620	4,693	25.2
Mayette (Grenoble)										636	139	21.8
San Jose										10,105	2,774	27.4
XXX Mayette										1,120	250	22.3
Payne							[1] 5,498	2,586	47.0	114,690	34,168	29.8
Kaghazi (Persian)										851	221	25.9
Placentia							[1] 400	293	73.3	73,943	19,830	26.8
Pride of Ventura										[1] 950	111	11.7
Praeparturiens										[1] 380	50	13.2
Santa Barbara										14,920	1,502	10.1
Willson										3,201	800	24.9
Hinds										8,952	660	7.4

[1] Pollinations made over a period less than 5 years; other pollinations performed for 5 years or longer.

Table 2 shows the results for each variety when pollinated by its own pollen (selfed), when pollinated by all other varieties of pollen, and when pollinated by wind under natural conditions.

TABLE 2.—*Summary of results of self-pollination, cross-pollination, and open pollination in some common varieties of Persian walnut, based upon the average of each variety*

Variety or species	Self-pollination			Cross-pollination			Open pollination		
	Pistils pollinated	Nuts matured	Pistils maturing nuts	Pistils pollinated	Nuts matured	Pistils maturing nuts	Pistils pollinated	Nuts matured	Pistils maturing nuts
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*	*Number*	*Number*	*Percent*
Concord	2, 661	1, 380	51. 8	3, 966	1, 757	44. 3	4, 682	1, 421	30. 4
El Monte	3, 040	553	18. 2	2, 410	598	24. 8	1, 871	870	46. 5
Eureka	17, 840	7, 872	44. 1	2, 840	1, 074	37. 8	15, 238	5, 696	37. 4
Golden Nugget	985	322	32. 7	1, 758	487	27. 7	1, 171	280	23. 9
Franquette	14, 024	4, 311	30. 7	23, 559	6, 954	29. 5	18, 620	4, 693	25. 2
Mayette (Grenoble)	440	289	65. 7				636	139	21. 8
XXX Mayette	590	180	30. 5	510	211	41. 4	1, 120	250	22. 3
Payne	26, 924	7, 311	27. 2	49, 738	16, 947	34. 1	114, 690	34, 168	29. 8
Kaghazi (Persian)	670	284	42. 4				851	221	25. 9
Placentia	5, 315	2, 612	49. 1	16, 959	7, 478	44. 1	73, 943	19, 830	26. 8
Pride of Ventura	850	80	9. 4				950	111	11. 7
Praeparturiens	1, 180	342	29. 0				380	50	13. 2
San Jose	12, 642	4, 389	34. 7	16, 069	5, 225	32. 5	10, 105	2, 774	27. 4
Santa Barbara	530	110	20. 8	2, 289	423	18. 5	14, 920	1, 502	10. 1
Willson	890	381	42. 8				3, 201	800	25. 0
Hinds							8, 952	660	7. 4

In table 3 is given the number of Payne and Placentia pistils pollinated each year for a period of years by each of the several varieties of pollen, also the percentage of nuts matured. The open pollinations, pollinations by self, and the average of all hand crosses for each year are also shown for convenience in making comparisons. For the Payne variety the figures are given for each of the 6 years 1922 to 1927, but on account of heavy blight during 1928 and frost injury during 1929, figures for those 2 years are not included. For the Placentia, pollinations for each of the 4 years 1925 to 1928 are given.

TABLE 3.—*Summary of pollination by years for the Payne and Placentia varieties of Persian walnut*

Variety or species of pollen applied	Year	Results of pollination					
		Payne			Placentia		
		Pistils pollinated	Pistils maturing nuts	Nuts matured	Pistils pollinated	Pistils maturing nuts	Nuts matured
		Number	*Number*	*Percent*	*Number*	*Number*	*Percent*
Concord	1922	130	20	15. 4			
	1923	640	140	21. 8			
	1924	150	20	13. 3			
	1925	920	180	19. 5			
	1926	900	207	23. 0			
	1927	359	149	41. 5			
	1928				180	110	61. 1
El Monte	1922	220	50	22. 7			
	1923	550	340	61. 8			
	1924	250	154	61. 6			
	1925	1, 020	400	39. 2			
	1926	220	70	31. 8			
	1927	620	510	82. 3			
	1928				480	320	66. 7
Ehrhardt	1928				275	61	22. 2
Eureka	1922	793	174	21. 9			
	1923	550	190	34. 5			
	1924	980	519	52. 9			
	1925	410	90	21. 9			
	1926	1, 720	905	52. 6			
	1927	1, 280	634	49. 5			
	1928				300	269	89. 7

TABLE 3.—*Summary of pollination by years for the Payne and Placentia varieties of Persian walnut*—Continued

Variety or species of pollen applied	Year	Results of pollination					
		Payne			Placentia		
		Pistils pollinated	Pistils maturing nuts	Nuts matured	Pistils pollinated	Pistils maturing nuts	Nuts matured
		Number	*Number*	*Percent*	*Number*	*Number*	*Percent*
Golden Nugget	1922	169	11	6.5	----	----	----
	1923	171	31	18.1	----	----	----
	1924	200	16	8.0	----	----	----
	1925	500	45	9.0	----	----	----
Mayette (Grenoble)	1922	750	270	36.0	----	----	----
	1923	1,080	490	45.3	----	----	----
	1924	1,070	480	44.9	----	----	----
	1925	1,690	540	31.9	----	----	----
	1926	2,110	630	29.8	----	----	----
	1927	2,570	933	36.3	----	----	----
	1928	----	----	----	444	331	74.5
Payne	1920	1,000	260	26.0	----	----	----
	1921	1,050	270	25.7	----	----	----
	1922	2,780	517	18.5	----	----	----
	1923	3,000	912	30.4	----	----	----
	1924	2,400	363	15.1	----	----	----
	1925	11,660	3,489	29.9	----	----	----
	1926	2,700	819	30.3	920	340	36.9
	1927	2,334	530	22.7	490	120	24.4
	1928				910	340	37.4
Kaghazi (Persian)	1928	----	----	----	280	221	78.9
Placentia	1925	350	75	21.4	1,890	683	36.1
	1926	2,750	734	26.6	770	640	83.1
	1927	1,450	341	23.5	790	617	78.1
	1928	----	----	----	1,865	671	36.0
Praeparturiens	1926	1,070	210	19.6	----	----	----
	1927	1,078	231	21.4	----	----	----
San Jose (Wiltz Mayette, San Jose Mayette)	1922	430	100	23.3	----	----	----
	1923	3,690	1,402	38.0	----	----	----
	1924	1,260	390	30.9	996	404	40.5
	1925	1,730	550	31.8	850	310	36.5
	1926	2,950	909	30.8	381	44	11.5
	1927	1,600	594	37.1	540	290	53.7
	1928	----	----	----	1,420	450	31.7
Santa Barbara	1922	1,110	200	18.0	----	----	----
	1925	329	33	10.0	----	----	----
	1926	940	149	15.8	----	----	----
	1927	780	171	21.9	----	----	----
	1928	----	----	----	330	270	81.8
Wasson	1926	----	----	----	529	160	30.2
	1927	----	----	----	1,570	420	26.7
	1928	----	----	----	440	160	36.3
Willson	1927	----	----	----	1,044	272	26.0
	1928	----	----	----	1,000	240	24.0
Hinds	1926	----	----	----	1,130	590	52.2
	1927	----	----	----	1,040	260	25.0
	1928	----	----	----	780	290	37.2
California black	1928	----	----	----	230	190	82.6
Japanese	1924	358	168	46.9	----	----	----
	1925	1,560	655	42.0	----	----	----
	1926	1,800	901	50.0	----	----	----
	1927	1,780	889	50.0	----	----	----
	1928	----	----	----	400	293	73.3
Open pollination	1920	1,196	226	18.8	----	----	----
	1921	6,080	1,347	22.1	----	----	----
	1922	11,370	3,018	26.5	----	----	----
	1923	7,677	1,783	23.2	----	----	----
	1924	14,180	3,183	22.4	42,110	12,126	28.7
	1925	30,010	10,733	35.7	1,633	264	16.1
	1926	21,662	7,080	32.7	13,690	2,790	20.3
	1927	22,515	6,925	30.7	12,600	2,240	17.7
	1928	----	----	----	3,910	2,410	61.6
All except self-pollination and open pollination	1922	3,602	826	22.9	----	----	----
	1923	6,681	2,576	38.5	----	----	----
	1924	4,268	2,325	54.5	----	----	----
	1925	8,509	2,573	30.2	850	310	36.5
	1926	14,460	4,716	32.6	2,960	603	20.3
	1927	11,517	4,483	38.9	4,684	1,362	29.1
	1928	----	----	----	7,169	3,345	46.6

In table 4 are shown the pollinations made each year in each locality for five common walnut varieties extensively grown in California.

TABLE 4.—*Number and variety of pistils pollinated, kinds of pollen used, and percentage of nuts matured for each method of pollination for each locality during each year*

POLLEN OF CONCORD VARIETY

Year and locality	Results when used to pollinate indicated varieties									
	Payne		Placentia		Franquette		San Jose		Eureka	
	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured
1922:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Linden	130	15								
Modesto									180	11
1923:										
Linden	200	25								
Oakdale	140	22								
Modesto	100	19								
San Jose	200	20								
1924:										
Linden	150	13								
Oakdale									280	12
1925:										
Linden	150	22								
Oakdale	200	20								
Modesto	200	18								
Waterford	100	22								
Sacramento	70	21								
San Jose	200	17								
1926:										
Linden	640	22								
Oakdale	100	24								
Waterford	60	27								
San Jose	100	26								
1927:										
Linden	100	38								
Oakdale	159	44								
San Jose	100	40								
1928:										
Ventura			180	61						

POLLEN OF EL MONTE VARIETY

Year and locality	Payne Pistils pollinated	Payne Nuts matured	Placentia Pistils pollinated	Placentia Nuts matured	Franquette Pistils pollinated	Franquette Nuts matured	San Jose Pistils pollinated	San Jose Nuts matured	Eureka Pistils pollinated	Eureka Nuts matured
1922:										
Linden	120	23								
Oakdale	100	21								
Modesto									80	50
Sacramento									150	61
1923:										
Linden	150	62								
Oakdale	100	58							170	40
Modesto	100	64								
Sacramento	100	55								
San Jose	100	69								
1924:										
Linden	50	62								
Oakdale	100	65								
San Jose	100	58								
1925:										
Linden	250	60								
Oakdale	100	34								
Waterford	170	44								
Sacramento	200	39								
San Jose	300	22								
1926:										
Linden	220	32								
1927:										
Linden	200	82								
Oakdale	200	79								
Modesto	220	86								
1928:										
Ventura			480	66						

TABLE 4.—*Number and variety of pistils pollinated, kinds of pollen used, and percentage of nuts matured for each method of pollination for each locality during each year*—Continued

POLLEN OF EHRHARDT VARIETY

Year and locality	Results when used to pollinate indicated varieties									
	Payne		Placentia		Franquette		San Jose		Eureka	
	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured
1928:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Ventura			275	22						

POLLEN OF EUREKA VARIETY

Year and locality	Payne: Pistils pollinated	Payne: Nuts matured	Placentia: Pistils pollinated	Placentia: Nuts matured	Franquette: Pistils pollinated	Franquette: Nuts matured	San Jose: Pistils pollinated	San Jose: Nuts matured	Eureka: Pistils pollinated	Eureka: Nuts matured
1921:										
Linden					500	24				
Modesto									500	35
1922:										
Linden	240	8			500	30	500	27		
Oakdale	233	20							780	51
Modesto	160	36								
San Jose	160	32								
1923:										
Linden	200	38			1,000	37	500	30		
Oakdale	200	30								
Sacramento									1,000	38
San Jose	150	34								
1924:										
Linden	380	50			1,000	35	100	32		
Oakdale	200	60							1,000	45
Modesto									3,000	40
Waterford	100	52								
Sacramento	100	55							3,180	42
Yuba City	100	49								
San Jose	100	53								
1925:										
Linden	100	24			500	25			500	25
Oakdale	200	22							1,000	27
Modesto									500	30
Waterford	110	20			500	20			600	35
Sacramento									1,000	30
Yuba City									1,000	32
San Fernando									500	33
1926:										
Linden	670	52								
Oakdale	380	55								
Waterford	360	50								
San Jose	310	54							500	46
1927:										
Linden	200	52								
Oakdale	200	46							500	72
Modesto	200	50								
Waterford	280	57							1,000	89
Yuba City	200	49							1,000	77
San Jose									280	52
Chico	200	40								
1928:										
Ventura			300	90						

POLLEN OF FRANQUETTE VARIETY

Year and locality	Payne: Pistils pollinated	Payne: Nuts matured	Placentia: Pistils pollinated	Placentia: Nuts matured	Franquette: Pistils pollinated	Franquette: Nuts matured	San Jose: Pistils pollinated	San Jose: Nuts matured	Eureka: Pistils pollinated	Eureka: Nuts matured
1920:										
Linden					990	27	1,040	31		
Oakdale					620	37				
Modesto					840	19	500	35		
San Jose					1,460	15	100	30		
1921:										
Linden					2,520	28	500	29		
San Jose					70	29	500	34		
1922:										
Linden					330	33	500	24		
Oakdale					190	83	500	20		
Modesto					570	54	100	25		
San Jose					350	23				

TABLE 4.—*Number and variety of pistils pollinated, kinds of pollen used, and percentage of nuts matured for each method of pollination for each locality during each year*—Continued

POLLEN OF FRANQUETTE VARIETY—Continued

Year and locality	Results when used to pollinate indicated varieties									
	Payne		Placentia		Franquette		San Jose		Eureka	
	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured
1923:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Linden							500	38		
Oakdale							499	40		
Modesto							200	33		
Sacramento							100	45		
San Jose							1,000	49		
Yolo					2,000	35				
1924:										
Linden					484	32	150	28		
Oakdale					300	33				
Modesto					250	40				
Waterford					200	40				
Ventura					500	24				
San Fernando					450	31				
1925:										
Linden					100	27	200	23		
Oakdale					100	23	300	20		
Modesto							600	18		
Waterford					500	21	300	25		
Sacramento					200	30	400	21		
Yuba City							500	20		
San Jose							100	25		
San Fernando					200	34				
1926:										
Linden					100	37	100	30		
Oakdale					100	30				
Sacramento							200	27		
1927:										
Waterford							100	35		
Yuba City					100	65				
San Jose					100	55	100	41		
1928:										
Yuba City					200	60	400	30		
1929:										
Linden							100	35		
Waterford					100	30				
Yuba City					100	33	200	31		
San Jose							250	38		

POLLEN OF GOLDEN NUGGET VARIETY

1922:										
Linden	169	6								
1923:										
Linden	171	12			3,130	19				
1924:										
Oakdale	200	8								
1925:										
San Jose	500	9								

POLLEN OF MAYETTE (GRENOBLE) VARIETY

1920:										
Linden					200	25				
1921:										
Linden					100	30				
San Jose					110	27				
1922:										
Linden	100	30								
Oakdale	200	42								
Modesto	150	38			140	29			70	14
San Jose	300	35								

TABLE 4.—*Number and variety of pistils pollinated, kinds of pollen used, and percentage of nuts matured for each method of pollination for each locality during each year*—Continued

POLLEN OF MAYETTE (GRENOBLE) VARIETY—Continued

Year and locality	Results when used to pollinate indicated varieties									
	Payne		Placentia		Franquette		San Jose		Eureka	
	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured
1923:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Linden	280	46			100	33				
Oakdale	300	48								
San Jose	500	43								
Yolo					200	41				
1924:										
Linden	300	49			100	29				
Oakdale	300	52								
Waterford	170	47								
San Jose	300	40								
1925:										
Linden	130	66								
Oakdale	480	26			100	18				
Modesto	200	32								
Waterford	300	30								
Sacramento	200	34								
Yuba City	200	27								
San Jose	180	31								
1926:										
Linden	750	36								
Oakdale	430	24								
Waterford	330	29								
Ventura	400	25								
San Jose	200	30								
1927:										
Linden	1,000	36								
Oakdale	200	35								
Modesto	200	42								
Waterford	200	37								
Yuba City	200	39			50	36				
Ventura	100	30								
Santa Paula	70	28								
San Jose	300	39								
Chico	300	34								
1928:										
Ventura			444	75						
Yuba City					100	71				

POLLEN OF XXX MAYETTE VARIETY

Year and locality	Payne: Pistils pollinated	Payne: Nuts matured	Placentia: Pistils pollinated	Placentia: Nuts matured	Franquette: Pistils pollinated	Franquette: Nuts matured	San Jose: Pistils pollinated	San Jose: Nuts matured	Eureka: Pistils pollinated	Eureka: Nuts matured
1922:										
Linden							500	26		
Oakdale					110	27				
1923:										
Linden							500	55		
Oakdale					400	58				
1924:										
Linden					100	35				
1925:										
Oakdale					100	30	400	30		
Waterford					100	35				
1927:										
Modesto					105	72				
Waterford					305	74				

POLLEN OF PAYNE VARIETY

Year and locality	Payne: Pistils pollinated	Payne: Nuts matured	Placentia: Pistils pollinated	Placentia: Nuts matured	Franquette: Pistils pollinated	Franquette: Nuts matured	San Jose: Pistils pollinated	San Jose: Nuts matured	Eureka: Pistils pollinated	Eureka: Nuts matured
1920:										
Linden	500	28								
San Jose	500	24								
1921:										
Linden	350	14			100	30				
Oakdale	200	33								
San Jose	500	31								

TABLE 4.—*Number and variety of pistils pollinated, kinds of pollen used, and percentage of nuts matured for each method of pollination for each locality during each year*—Continued

POLLEN OF PAYNE VARIETY—Continued

Year and locality	Results when used to pollinate indicated varieties									
	Payne		Placentia		Franquette		San Jose		Eureka	
	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured
1922:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Linden	1,240	18			100	20	500	23		
Oakdale	1,080	19			100	25				
Modesto									90	22
San Jose	160	12			200	27				
Chico	300	23								
1923:										
Linden	500	31			100	30	500	39	610	51
Oakdale	300	30			100	32				
Modesto	100	30								
Waterford	1,000	34								
Sacramento	100	27							1,000	47
San Jose	500	26								
King City	500	28								
Yolo					100	27				
1924:										
Linden	1,000	15								
Oakdale	300	12								
Waterford	500	17								
Ventura	100	22								
San Jose	500	14								
1925:										
Linden	4,310	32			100	19				
Oakdale	720	56			100	15				
Waterford	1,830	26			100	23				
Sacramento	1,000	23								
Yuba City	1,000	30								
Ventura	300	25								
San Jose	800	23								
King City	1,700	26								
1926:										
Linden	1,000	29								
Oakdale	450	34								
Ventura	100	34	920	37						
San Jose	750	28								
King City	400	33								
1927:										
Linden	730	31								
Oakdale	200	26								
Modesto	300	30								
Waterford	200	35								
Yuba City	300	32			80	25				
Ventura	200	24	490	24						
San Jose	300	29								
Chico	104	31								
1928:										
Yuba City					100	20				
Ventura			910	37						

POLLEN OF KAGHAZI (PERSIAN) VARIETY

1928:										
Ventura			280	79						

POLLEN OF PLACENTIA VARIETY

1925:										
Linden	350	21								
Ventura			1,400	40						
Santa Paula			490	25						
1926:										
Linden	1,700	24								
Waterford	1,050	31								
Ventura			770	83						

TABLE 4.—*Number and variety of pistils pollinated, kinds of pollen used, and percentage of nuts matured for each method of pollination for each location during each year*—Continued

Year and locality	Results when used to pollinate indicated varieties									
	Payne		Placentia		Franquette		San Jose		Eureka	
	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured
POLLEN OF PLACENTIA VARIETY—Continued										
1927:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Linden	1,450	23								
Ventura			790	78						
1928:										
Ventura			1,865	36						
POLLEN OF PRAEPARTURIENS VARIETY										
1926:										
Linden	1,070	20								
1927:										
Linden	1,078	21								
POLLEN OF SAN JOSE VARIETY										
1920:										
Linden					870	21	1,960	24		
Oakdale					500	30				
Modesto					500	34	280	36		
Waterford							640	31		
San Jose					489	26	520	12		
1921:										
Linden					280	12	540	16		
Oakdale					170	41				
1922:										
Linden					400	31	680	41		
Oakdale					200	25	350	60		
Modesto					100	21	170	36	140	15
Sacramento									70	10
San Jose	430	23			600	23				
1923:										
Linden	190	53			500	31	1,000	52		
Oakdale					360	36	500	50		
Modesto	500	38			100	35	100	55		
Waterford	1,000	35			500	37				
Sacramento	1,000	31					200	35		
San Jose	1,000	45			110	30	502	40		
Yolo					400	36				
1924:										
Linden					200	34	500	33		
Oakdale					100	37				
Waterford	700	32			200	24				
Ventura	210	30	996	40	100	26				
San Jose	350	26								
San Fernando					400	33				
1925:										
Linden	440	51			800	23	300	30		
Oakdale							500	35		
Modesto	40	35					100	41		
Waterford					400	21	200	36		
Sacramento	250	33					300	30		
Yuba City							100	20		
Ventura	500	15	850	36						
San Jose	500	31			100	20	500	32		
San Fernando					500	19				
1926:										
Linden	830	36			100	26	500	33		
Oakdale	1,260	30			100	21				
Waterford	430	31								
Ventura			381	12						
San Jose	430	23								

TABLE 4.—*Number and variety of pistils pollinated, kinds of pollen used, and percentage of nuts matured for each method of pollination for each locality during each year*—Continued

POLLEN OF SAN JOSE VARIETY—Continued

Year and locality	Results when used to pollinate indicated varieties									
	Payne		Placentia		Franquette		San Jose		Eureka	
	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured
1927:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Linden							300	40		
Oakdale	460	27								
Waterford	500	29					100	48		
Yuba City	440	49			500	44				
Ventura			540	43						
San Jose	200	55			350	42	1,000	49		
1928:										
Yuba City					300	26	300	21		
Ventura			1,420	28						
1929:										
Linden					500	45	200	52		
Waterford					1,000	35				
Yuba City					500	30	100	34		
San Jose					500	32	200	40		

POLLEN OF SANTA BARBARA VARIETY

1922:										
Linden	170	6								
San Jose	940	20								
1925:										
Linden	329	10								
1926:										
Linden	510	17								
Oakdale	400	14								
San Jose	30	21								
1927:										
Linden	780	22								
1928:										
Ventura			330	82						

POLLEN OF WASSON VARIETY

1926:										
Ventura			529	30						
1927:										
Ventura			1,570	55						
1928:										
Ventura			440	36						

POLLEN OF WILLSON VARIETY

1925:										
Ventura			1,044	26						
1928:										
Ventura			1,000	24						

POLLEN OF HINDS WALNUT

1921:										
Linden							1,070	45		
1922:										
Linden							460	30		
1924:										
Linden							1,000	33		
1926:										
Ventura			1,130	52						
1927:										
Ventura			1,040	25						
1928:										
Ventura			780	37						

TABLE 4.—*Number and variety of pistils pollinated, kinds of pollen used, and percentage of nuts matured for each method of pollination for each locality during each year*—Continued

Year and locality	Results when used to pollinate indicated varieties									
	Payne		Placentia		Franquette		San Jose		Eureka	
	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured
POLLEN OF CALIFORNIA BLACK WALNUT										
1928:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Ventura			230	82						
POLLEN OF JAPANESE WALNUT										
1924:										
Linden	358	47								
1925:										
Linden	1, 560	42								
1926:										
Linden	1, 800	50								
1927:										
Linden	1, 780	50								
1928:										
Ventura			400	73						
OPEN POLLINATION										
1920:										
Linden	500	16			180	11	920	32		
Oakdale					500	19				
Modesto					100	20				
San Jose	696	21			300	22	100	29		
1921:										
Linden	1, 180	12			470	15	200	25		
Oakdale	400	20			280	36				
Modesto									800	52
Sacramento	3, 000	23								
San Jose	1, 500	29			300	20	500	27		
1922:										
Linden	2, 250	20			470	15	420	28		
Oakdale	2, 580	26			570	45	940	17	1, 061	15
Modesto	1, 640	25			280	36	300	57	360	11
Sacramento	500	29							1, 970	18
San Jose	3, 300	24			750	22				
Chico	1, 100	20								
1923:										
Linden	1, 000	20			1, 000	25	500	30	500	65
Oakdale	1, 000	16			500	29	500	25		
Modesto	1, 800	25			500	27	200	35		
Waterford	1, 000	31			1, 000	24				
Sacramento	881	30					250	32	1, 000	45
San Jose	1, 000	27			200	40	200	30		
King City	996	13								
Yolo					1, 000	6				
1924:										
Linden	1, 000	20			100	31	300	27		
Oakdale	1, 000	17			100	29			500	40
Modesto	500	23			100	33			500	30
Waterford	1, 880	15	10, 000	29	100	25				
Sacramento	2, 000	26							457	35
Yuba City	1, 800	18	10, 000	33						
Ventura	1, 200	19	20, 000	27	100	10				
San Jose	4, 800	28								
San Fernando					100	14				
King City			2, 110	23						
1925:										
Linden	13, 010	37			100	29	500	22	500	20
Oakdale	2, 000	36			320	20	500	24	1, 940	19
Modesto	1, 000	40					100	20	200	18
Waterford	4, 500	41			500	25	100	16		
Sacramento	1, 500	37			500	34	500	20		
Yuba City	1, 500	36							500	25
Ventura	500	20	1, 633	16	500	22				
San Jose	2, 000	34			500	25	350	25		
San Fernando					500	15				
King City	4, 000	32								

TABLE 4.—*Number and variety of pistils pollinated, kinds of pollen used, and percentage of nuts matured for each method of pollination for each locality during each year*—Continued

OPEN POLLINATION—Continued

Year and locality	Results when used to pollinate indicated varieties									
	Payne		Placentia		Franquette		San Jose		Eureka	
	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured	Pistils pollinated	Nuts matured
1926:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Linden	1,446	30			500	42	200	20		
Oakdale	2,500	37			200	36				
Waterford	2,216	35								
Sacramento							240	22		
Yuba City	5,000	38								
Ventura	2,000	33	13,690	20						
San Jose	3,500	31							500	37
King City	5,000	26								
1927:										
Linden	1,365	17					100	27		
Oakdale	4,050	35							1,000	50
Modesto	500	25								
Waterford	5,000	30			500	34	100	29	1,000	56
Sacramento	5,000	35								
Yuba City	4,000	31			500	28			1,000	61
Ventura	500	25	12,600	18						
Santa Paula	100	26								
San Jose	1,000	18			1,000	25	400	32	1,450	66
Chico	1,000	33								
1928:										
Yuba City					1,000	17	500	20		
Ventura			3,910	62						
1929:										
Linden					1,000	29	200	27		
Waterford					1,000	31				
Yuba City					500	19	500	25		
San Jose					500	30	485	23		

Some of the nuts matured from various crosses were cracked and examined. Table 5 shows the percentage of good and of defective nuts obtained in each case.

TABLE 5.—*Comparison of proportion of good and defective nuts following self-pollination, cross-pollination, and open pollination of certain walnut varieties*

Year	Variety and pollination	Nuts examined	Good nuts		Defective nuts	
		Number	*Number*	*Percent*	*Number*	*Percent*
1920	Franquette×self	66	66	100	0	0
	Franquette×San Jose	18	18	100	0	0
	Franquette×open pollination	12	12	100	0	0
1920	San Jose×self	41	33	80.5	8	19.5
	San Jose×Franquette	32	32	100	0	0
	San Jose×open pollination	30	28	93.4	2	6.6
1921	Franquette×self	20	20	100	0	0
	Franquette×San Jose	18	18	100	0	0
1921	San Jose×self	60	40	66.7	20	33.3
	San Jose×Hinds	49	49	100	0	0
1921	Payne×self	50	50	100	0	0
	Payne×open pollination	100	100	100	0	0
1922	Payne×self	23	23	100	0	0
	Payne×Concord	24	24	100	0	0
	Payne×El Monte	50	50	100	0	0
	Payne×Eureka	80	80	100	0	0
	Payne×Golden Nugget	10	10	100	0	0
	Payne×open pollination	58	58	100	0	0
1924	Eureka×self	134	122	91.1	12	8.9
	Eureka×open pollination	36	36	100	0	0

TABLE 5.—*Comparison of proportion of good and defective nuts following self-pollination, cross-pollination, and open pollination of certain walnut varieties*—Continued

Year	Variety and pollination	Nuts examined	Good nuts		Defective nuts	
		Number	*Number*	*Percent*	*Number*	*Percent*
1925	Payne×self	770	540	70.1	230	29.9
	Payne×Concord	140	140	100	0	0
	Payne×El Monte	134	134	100	0	0
	Payne×Eureka	19	19	100	0	0
	Payne×Mayette (Early Blooming)	220	200	90.9	20	9.1
	Payne×San Jose	48	39	81.2	9	18.8
	Payne×Placentia	41	38	92.7	3	7.3
	Payne×Praeparturiens	21	21	100	0	0
	Payne×open pollination	470	353	75.1	117	24.9
1925	Placentia×self	68	66	97	2	3
	Placentia×Payne	46	38	82.6	8	17.4
	Placentia×San Jose	75	63	84	12	16
	Placentia×Wasson	16	12	75	4	25
	Placentia×Willson	26	26	100	0	0
	Placentia×open pollination	240	240	100	0	0
1925	Santa Barbara×self	40	38	95	2	5
	Santa Barbara×Payne	20	20	100	0	0
	Santa Barbara×Placentia	30	30	100	0	0
	Santa Barbara×Willson	40	36	90	4	10
	Santa Barbara×open pollination	66	66	100	0	0
1926	Payne×self	120	96	80	24	20
	Payne×Concord	145	145	100	0	0
	Payne×Eureka	135	135	100	0	0
	Payne×Mayette (Early Blooming)	490	490	100	0	0
	Payne×San Jose	100	100	100	0	0
	Payne×Placentia	41	41	100	0	0
	Payne×Praeparturiens	21	21	100	0	0
	Payne×*Juglans sieboldiana*	90	90	100	0	0
	Payne×open pollination	1,167	1,104	94.6	63	5.4
1927	Payne×self	176	140	79.5	36	20.5
	Payne×San Jose	54	33	61.1	21	38.9
	Payne×Santa Barbara	20	13	65	7	35
	Payne×open pollination	268	220	82	48	18
1928	Payne×self	500	375	75	125	25
	Payne×Santa Barbara	300	200	66.7	100	33.3

RESULTS OF SELF-POLLINATION AND CROSS-POLLINATION

An examination of tables 1, 2, and 4 shows that in all varieties of Persian walnut upon which experiments have been conducted there is no case of self-sterility or intersterility. Each variety was found to be markedly self-fertile, and all the varieties crossed were interfertile. Furthermore, all the varieties that were pollinated by any of three other species—the Hinds walnut, the California black, and the Japanese walnut—matured nuts.

A comparison of the results of open pollination, in the commercial orchards in which the tests were made, with the selfings and crosses suggests that any of the combinations will give a sufficient set of nuts to produce normal commercial crops if other conditions are favorable. So far as adequate tests have been made, it must be concluded that the grower, whether he is depending upon self-pollination or cross-pollination, cannot ascribe crop failure to lack of natural compatibility between pistil and pollen.[4]

On the other hand, it may well be that certain combinations are especially favorable to crop production. Thus the Payne pollinated by El Monte and by Eureka and the Placentia when selfed, gave high percentages of set. A study of tables 1 and 4 will disclose other examples. Table 3 shows that the Payne and Placentia are reason-

[4] In many cases where the percentage of set in table 1 is very low, as, for example, in the Santa Barbara pistils pollinated by El Monte pollen, it will be noted that the number of pollinations involved is too small to be conclusive.

ably consistent in this from year to year, although in some years the set is low. The Payne gave heavier crops each year with Eureka, El Monte, Placentia, and Japanese walnut pollens than with the Golden Nugget, Praeparturiens, or Santa Barbara pollens. The Placentia when selfed gave a relatively high set for each of four years. It appears that some varieties of pollen tend to give a better set than others upon all varieties of pistils, with perhaps an occasional exception. A high set generally results from the application of Eureka, Mayette, and San Jose pollens. (See tables 1 and 4.) In the same manner some pollens, such as those of Golden Nugget and Santa Barbara, usually give a light set. Table 1 suggests also that the pistils of certain varieties tend to set nuts better than others.

Concord and Placentia pistils pollinated by almost any variety of pollen gave a high percentage of set. This may be one reason why these varieties have been considered in general to be good bearers. The Payne does not as a rule set as high percentages as the Placentia, but examination of the trees shows such a large number of pistillate flowers, even on young trees, that the crop may be heavy when the percentage of set is relatively low. So far as experiments have shown the Santa Barbara pistils have given low percentages of set with pollen of most varieties.[5]

Through further experimentation it may be possible to find combinations of pistils and pollens that will greatly increase commercial yields, although, as will be seen later, other factors besides degree of compatibility will have to be taken into account in the interplanting of varieties.

It is a matter of importance to growers to know whether, in general, cross-pollination is more effective than self-pollination. Table 1 shows no regularity in the results of selfings as compared with crosses. The Concord when selfed gave a high percentage of set (51.8 percent), but El Monte gave a low set (18.2 percent). The other varieties show all gradations between these two. The very low set of Pride of Ventura (9.4 percent) and the very high set of Mayette (65.7 percent) must be questioned, because the number of pollinations was small and in each case the experiment was conducted for one year only. A high set is, however, more valuable as an indication of the degree of compatibility of pistil and pollen than a low set, because when the set is low many factors besides pollination may have affected the results by causing the nuts to drop or to fail to develop. If in general the cross-pollinations resulted in a larger set of nuts than the selfings, it would seem that the fact would become apparent from the data in table 2, but there it is seen that in some cases the crosses and in others the selfings gave the better set, while the two for the most part ran close enough together to make the practical results about the same. The data in table 5 suggest that the percentage of defective nuts may be higher in the selfings than in the crosses. There are striking exceptions, and further experimentation is necessary before conclusions can be drawn.

It will be noticed that most varieties when selfed gave sets that compare favorably with the crosses and would undoubtedly give a commercial crop under conditions favorable to pollination and crop production.

[5] Because the Santa Barbara group includes many types of trees, pollen for selfing was taken from the same tree.

There is no doubt that some seasons are more favorable to crop production than others. Thus the set of Payne in 1927 (table 3) pollinated by nine varieties was in all but one case higher than the set of Payne by the same pollens in 1925. It will be noted, however, that the open pollinations show the opposite results. This was due to the fact that conditions in 1925 were somewhat more favorable for natural pollination than in 1927.

Table 4 gives some opportunity to compare the behavior of varieties in various localities and seasons. It is necessarily incomplete, since all the varieties are not grown in each district and could not be reached in every season. Table 4 shows that the varieties and species tested were interfertile and self-fertile in all districts and seasons and that no case of incompatibility was recorded. This table will be found convenient for growers who wish to study the behavior of varieties in their own localities.

In drawing conclusions from the tables it must be remembered that pollination is only one of the factors affecting the setting and development of walnuts. Whenever the effects of frost, blight, or insects were known to interfere, the results were thrown out; but such factors as these, operating in lesser degree, undoubtedly caused the results to vary somewhat from year to year. The age of the tree and the amount of moisture in the soil no doubt affect the results, as do fogs, rains, winds, heat, and cold, during the blooming period. The viability of the pollen and the condition of the pistil when pollinated are also factors (p. 42). A parthenogenetic set found to occur at times under conditions not fully analyzed as yet (p. 49) may affect the results slightly. For all these reasons the tables must be interpreted rather loosely and the results regarded as indicative rather than conclusive. The larger the number of pollinations, localities, and seasons, the more dependable the results. It can be said with certainty, however, that all varieties tested are both self-fertile and interfertile, and that failure of the nuts to set or mature is not due to incompatibility of pistil and pollen, but results from other causes.

DICHOGAMY

BLOOMING HABIT WITH RELATION TO DICHOGAMY

Although artificial pollination has established the fact that the varieties of Persian walnut usually grown in California are self-fertile and interfertile, it is obvious that if a variety is to pollinate itself the catkins must produce pollen at the time the pistils are receptive. Likewise, for interpollination the staminate bloom of one variety must produce pollen at the time the pistillate bloom of the other variety is ready to receive it. In artificial pollination under favorable conditions the pollen may be carried long distances, but in the orchard pollen and pistil must be ready in the same place at the same time. When there is no overlapping of the periods of maturity of pistil and pollen, the plant (or variety) is said to be dichogamous and cannot pollinate itself, no matter how compatible pistil and pollen might otherwise be. When dichogamy is not quite complete, the overlapping may still be so slight as to give little opportunity for pollination to occur. The form of dichogamy in which the pistils precede the stamens in development is called protogyny. That form of dichogamy in which the development of the stamens precedes that of the pistils is known as protandry.

It has long been known that many monoecious plants are dichogamous. Dichogamy, as existing in the family of plants to which the walnut belongs (Juglandaceae), was probably first mentioned by Delpino (*5*). According to Kerner (*7, 1895 ed.*) all monoecious plants, especially alders, birches, walnuts, planes, elms, oaks, hazels, and beeches, are markedly protogynous. On the other hand, in a paper read before the California State Horticultural Society in 1883 Jessup[6] called attention to the protandrous character of certain Persian walnut trees he had observed during 1878, 1879, and 1880. Lelong (*9, p. 9*) wrote of protandry in the walnut as follows:

> The male flowers, or staminate catkins, are the first to appear, and come out generally together with the first growth of the tree, although in many instances they appear before the trees put forth, but about the time they begin to show signs of growth. The female blossoms, or pistillates, appear much later, from one to three weeks intervening.

Allen (*2, p. 21*) wrote that among the faults of the English walnut is the "irregular and unequal blooming habit of its pistillate and staminate blossoms, and the consequent failure of the former to be fertilized and to develop nuts; * * *." He informs us further that pistillate and staminate flowers mature at the same time in the best varieties, insuring fertilization and productivity. Lake (*8, p. 76–78*) made the following statements in regard to pollination:

> Before deciding what varieties to plant, ample pollination must be assured, as otherwise generous crops cannot be produced. * * * Not infrequently these two kinds of blossoms (staminate and pistillate) do not mature at the same time upon the same tree, or one or the other of them is infertile because of imperfect development. * * * In some instances of shy bearing it may be desirable to introduce a variety rich in pollen, regardless of the character of its nuts, in order to amply fertilize the blossoms of the more valuable varieties. * * * Until ample investigation has been made it is safe to plant only varieties of known value as pollinizers, leaving the work of testing varieties not so well known to the State or Nation, except as the enthusiastic amateur finds it advantageous to make trials of promising new varieties.

Thus it will be seen that such observations and comments as have been made are general in nature and appear contradictory as to the type of dichogamy. There has been no compilation of data to show which varieties, if any, are subject to complete dichogamy or to incomplete dichogamy sufficient in degree to prevent a commercial set of nuts, or to determine the extent to which protogyny or protandry occur, or to establish a basis for the selection of varieties to be interplanted for pollination purposes. If any varieties are dichogamous to any considerable extent, obviously they should not be planted in solid blocks, but should be interplanted with other varieties in such arrangements as will best provide for cross-pollination. Accordingly, a study has been made of the blooming habits of 17 varieties of Persian walnut, with special reference to dichogamy. Observations were made for each variety in as many districts and seasons as practicable over a period of 10 years (1920 to 1929) and over a geographical area possessing the main types of California climate in which walnuts are grown. The results of these observations and studies are pre-

[6] JESSUP, W.W. Paper read before the California State Horticultural Society, Apr. 27, 1883.

sented graphically in figures 7 and 8. The lines do not indicate the behavior of a single tree or orchard, but represent the average of all the orchards of the given variety that could be visited in the locality named. About 200 averages of dichogamy records for various districts were made, exclusive of those taken in years when frost or rain made the studies incomplete by destroying pistils or staminate catkins.

In general it was found that none of the varieties was completely dichogamous at all times and under all circumstances, but all except four (in which the total number of records do not exceed five in any case and for which, therefore, the evidence cannot be taken as conclusive) were either completely or practically dichogamous in some seasons and places. Thirty-four records out of 200 show that self pollination would have been impossible with any given variety. The dotted areas between the lines indicate the presence of a few scattered pistils (or staminate catkins) in maturity and are given as a matter of botanical rather than of practical interest. In several cases the last of the catkins ceased to shed pollen as many as five days before the first of the pistils was receptive, e.g., Eureka at Santa Susana in 1929 and Franquette at Waterford in 1929.

Furthermore, there are 7 records showing effective overlap during 1 day only, 14 showing an overlap of 2 days only, and 17 an overlap of 3 days only. An overlap of only 1 day means little in a practical way, but any appreciable number of receptive stigmas (or of catkins shedding pollen when the variety was protogynous in tendency) was considered of sufficient botanical importance to be recorded. A 2-day or 3-day overlap is more important, but hardly allows time for the pistils to become receptive in large numbers before the pollen is gone (or vice versa). The efficacy of 2 or 3 days of overlapping bloom depends largely upon the weather, as affecting both the rate of bloom and the distribution of pollen. In most cases, however, where the overlap is so slight it will be noticed that by far the greater number of the pistils must go unpollinated. It will appear that on all these occasions the chance for adequate self-pollination in orchards of a single variety was very slight. In other words, in 78 out of 200 recorded averages cross-pollination would be required for reasonable commercial security because of the dichogamous tendencies of this species of walnut. In individual orchards the hazard may be still greater, because there is often a difference of several days in blooming dates in a given district, traceable to such influences as age of trees, general conditions of the orchards, or exposure.

DICHOGAMOUS TENDENCIES AS EXHIBITED IN VARIETIES

It seems probable that variations in the extent and character of the dichogamous tendencies in the walnut depend, at least to some extent, upon variety. In the Concord, Eureka, Golden Nugget, Franquette, Mayettes (Early Blooming and Grenoble),[7] San Jose, XXX Mayette, Payne, and Praeparturiens, the period of staminate bloom began earlier than that of the pistillate bloom in all the cases studied. While these varieties may be considered protandrous in tendency, they differed in the degree of protandry (fig. 7). The Franquette, San Jose, Payne, and Eureka were especially protandrous

[7] For a brief description of these varieties, see List of Varieties, p. 50.

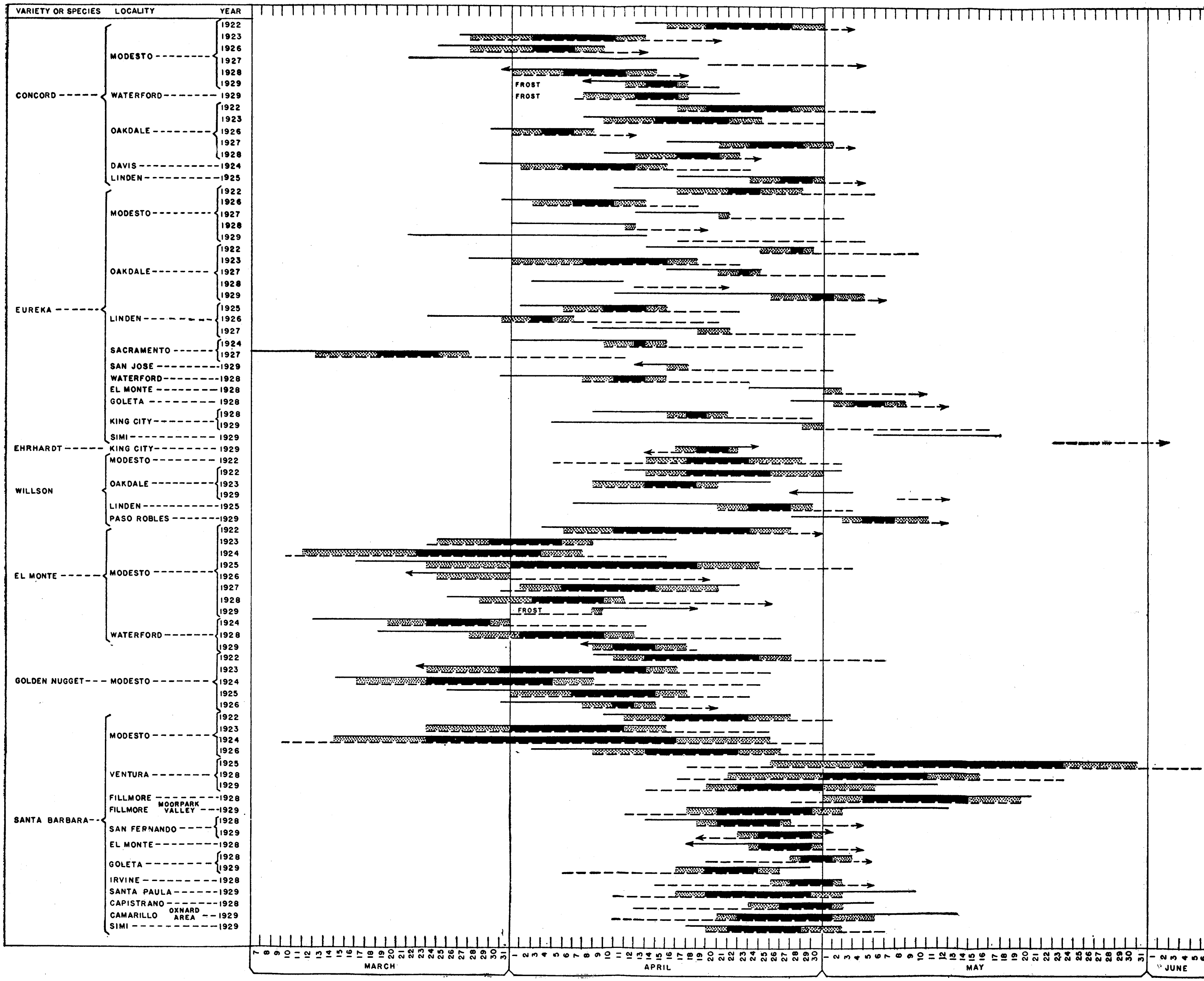

FIGURE 7, *A*.—Average period of bloom of walnut varieties and species in various California localities, showing the relation of the period of pollen shedding to the period of pistil receptivity. (For explanatory legend, see fig. 7, *C*. In the list of localities, above, for the Santa Barbara variety, the item reading "Fillmore Moorpark Valley" should be "Fillmore, Moorpark"; the next item, "San Fernando", should be "San Fernando Valley"; and "Capistrano" should be "San Juan Capistrano".)

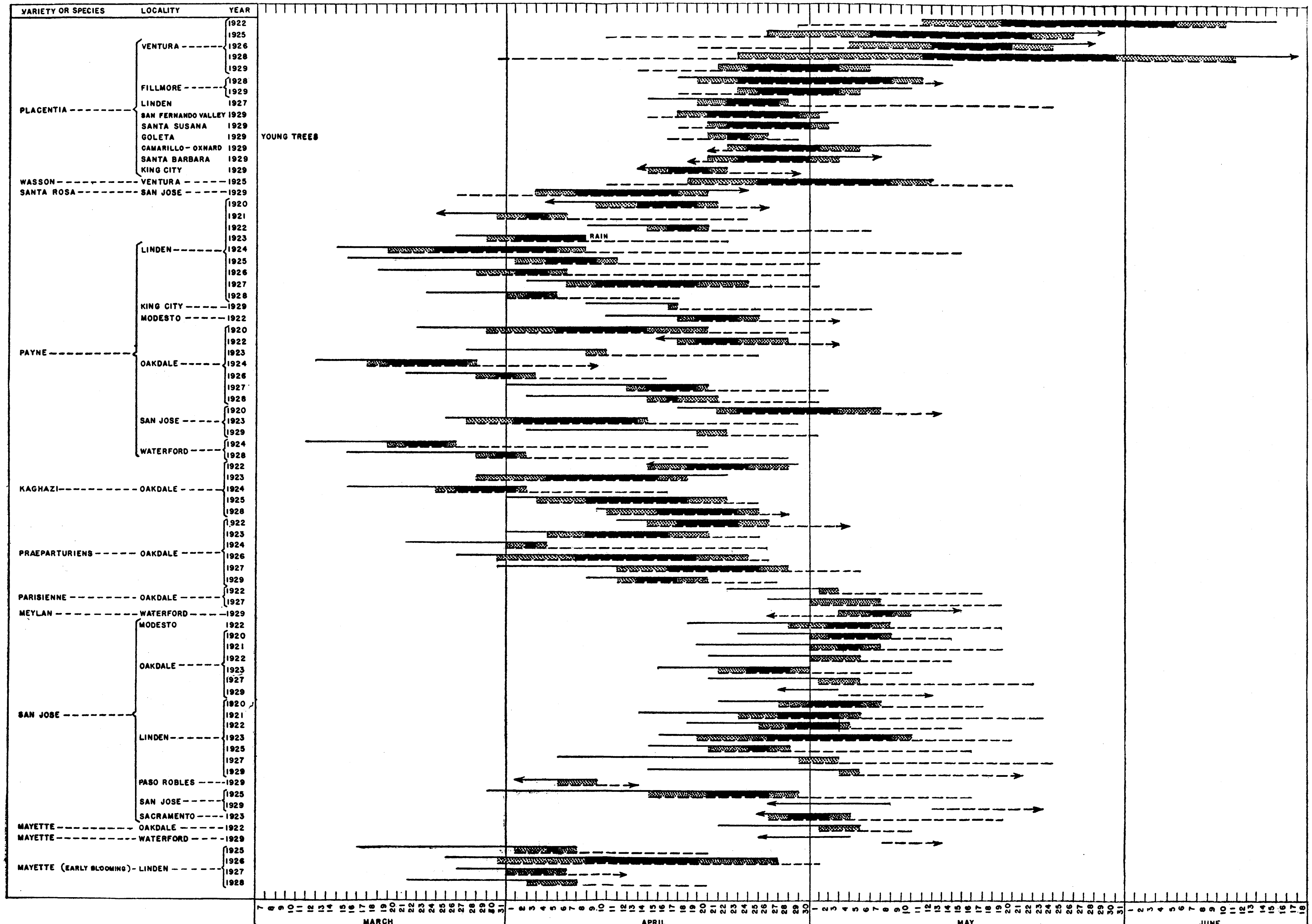

FIGURE 7, *B*.—Average period of bloom of walnut varieties and species in various California localities, showing the relation of the period of pollen shedding to the period of pistil receptivity. (For explanatory legend, see fig. 7, *C*.)

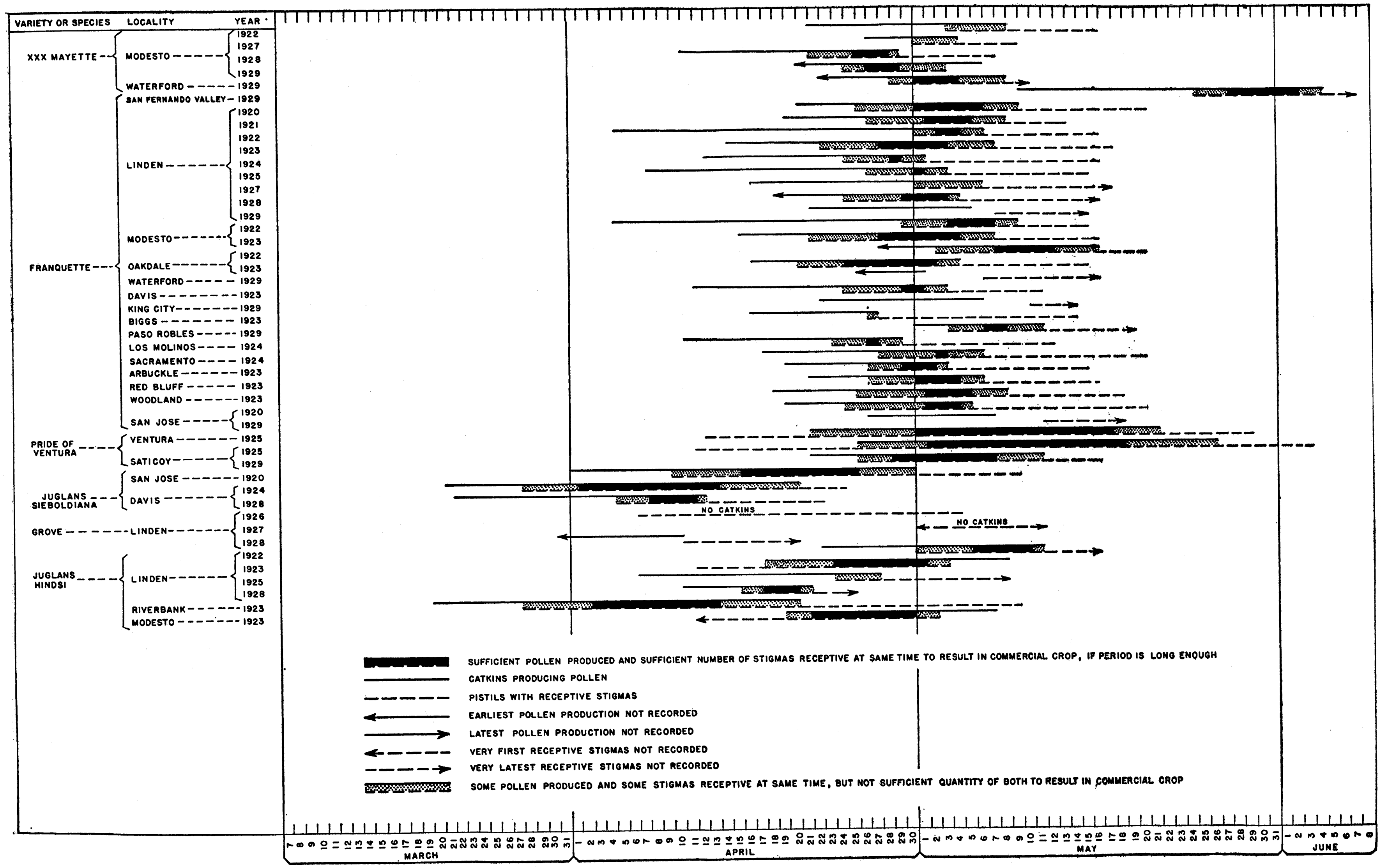

FIGURE 7, *C*.—Average period of bloom of walnut varieties and species in various California localities, showing the relation of the period of pollen shedding to the period of pistil receptivity.

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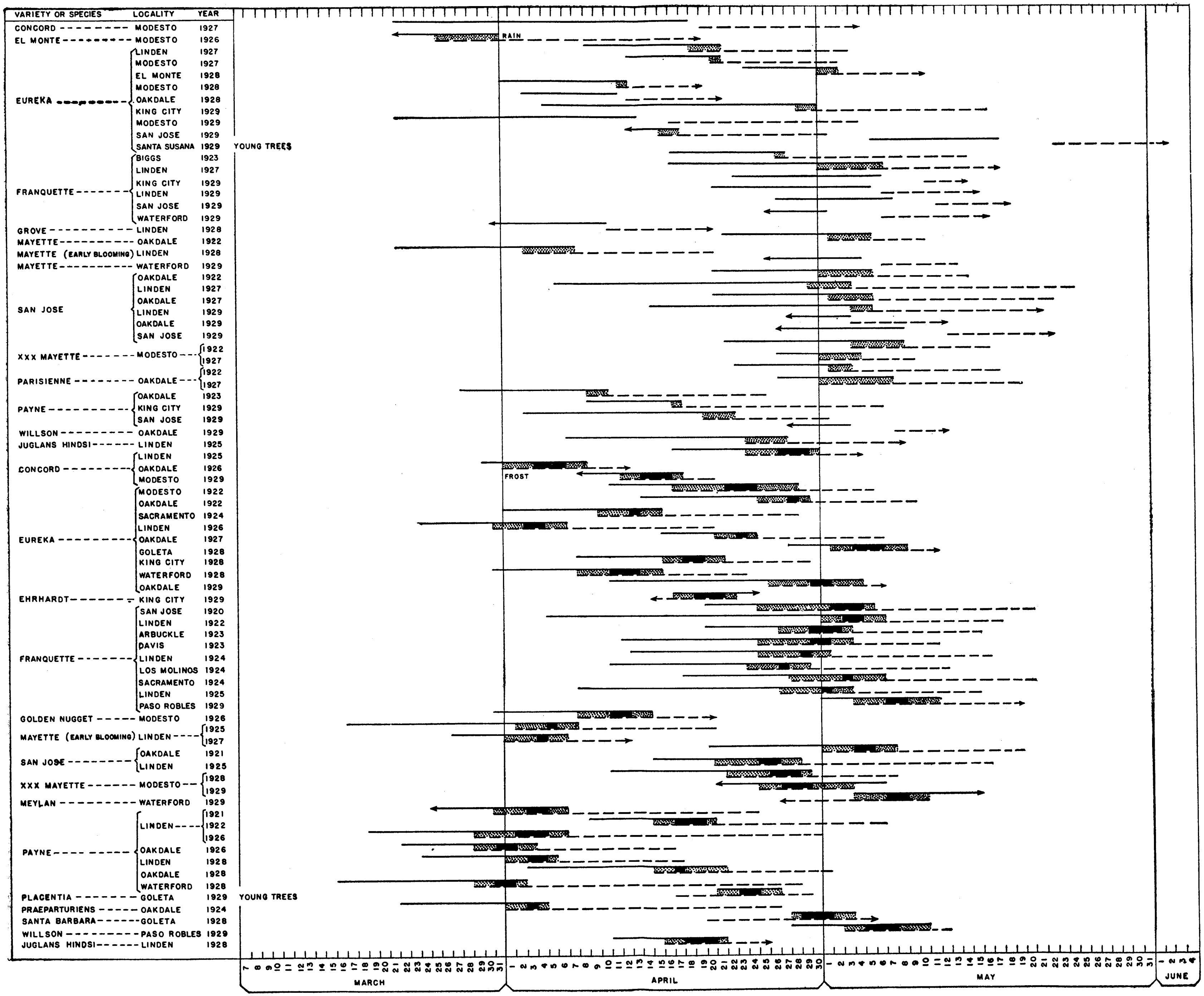

Figure 8.—Average period of bloom of walnut varieties and species, showing dichogamy practically complete. An explanatory legend appears on figure 7, *C.*

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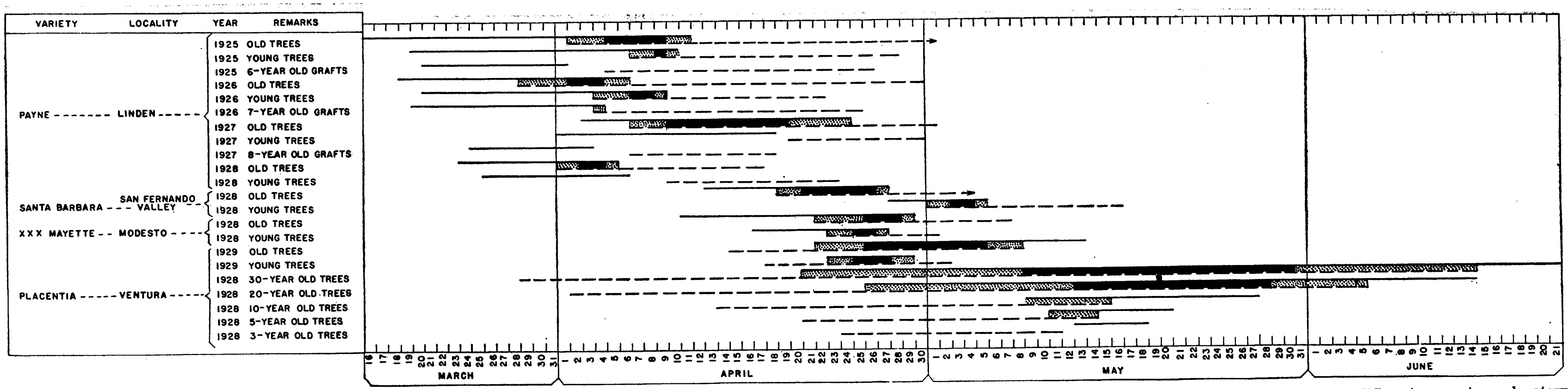

FIGURE 9.—Average period of bloom of Payne, Santa Barbara, Mayette, and Placentia walnut varieties, showing the relation of the period of pollen shedding to the period of pistil receptivity in trees of different ages. An explanatory legend appears on figure 7, *C*.

182781°—34. (Face p. 26.) No. 5.

in that the catkins developed regularly far ahead of the pistils, and quantities of the pistils bloomed after all the catkins were gone. In these four varieties practically complete dichogamy was relatively frequent. In 9 out of 22 studies of the Eureka there was no effective overlapping of the staminate and pistillate bloom, and in 17 the overlapping was 3 days or less and could hardly be effective from a commercial standpoint. Similarly in 26 studies of the Franquette, 15 cases showed conditions unsatisfactory for self-pollination.

Another group of varieties was sometimes protandrous and sometimes protogynous, with protandry apparently predominating. These included El Monte, Willson, and Kaghazi. The Grove and Parisienne were protandrous when they produced catkins (fig. 7).

A third group was predominantly protogynous in tendency, but not always so. The varieties most studied in this group were the Placentia and Santa Barbara. In 11 of the 14 studies of the Placentia, the pistils came out first and the catkins first in 3. In 13 out of 20 studies of the Santa Barbara, the pistillate flowers came out first, and in 7 the staminate flowers first. The available evidence suggests that Pride of Ventura, Ehrhardt, Meylan, Lucretia, and Santa Rosa are protogynous in tendency, but positive conclusions should not be drawn in regard to these five varieties until further data are obtained.

It will be seen from figures 7 and 8, that the varieties in the second and third groups are much more satisfactory as self-pollinizers than those in the first. The Placentia, for example, is much more likely to produce crops when planted alone than is the Franquette. The Franquette, because of its many excellent qualities, has been planted extensively in central California, but when planted in solid blocks it has not been successful and has caused much loss because of shy bearing. Orchards of the variety have been removed because of repeated light crops. As it happens, the protogynous varieties are grown largely in districts in which the climate increases the tendency toward protogyny, while some of the protandrous varieties are grown almost exclusively where the climate tends to increase protandry (p. 33). Where there was opportunity for observation it was found that varieties having protogynous tendencies were likely to pollinate themselves well in districts in which the influence of the climate was toward protandry. In some cases the influence of the climate and season upon protogynous varieties caused the catkins to begin to bloom first, but in such cases they were not as far in advance of the pistils as were the catkins of the protandrous varieties in the same localities and season.

RELATION OF AGE OF TREE TO DICHOGAMY

Young trees of all varieties, whether protandrous or protogynous in tendency, are much more subject to dichogamy than are old trees. This fact does not affect the data in figures 7 and 8, except in a few cases where the average age of the trees studied was low enough to be significant. In such cases the fact is noted in the figures. In figure 9 are illustrated the differences in the overlapping of the staminate and pistillate bloom in trees of different ages growing under practically identical conditions. The orchards were close together and similarly situated, thus affording favorable opportunity for comparison. It was not always possible to get the exact age of old trees, but those marked "old trees" were at least 30 years old, and the "young trees" were less than 15 years of age. There is no doubt that in all varieties of walnuts the dichogamous tendency decreases with age, but in none of the trees studied had the tendency disappeared, although some were over 50 years old. No grower can afford to wait for his trees to pollinate themselves if they do not do so at the age of 10 or 12 years.

COMPARATIVE BLOOMING DATES OF VARIETIES

One of the inherent tendencies of walnut varieties that manifests itself in all climates and seasons is the relative time of bloom. Thus,

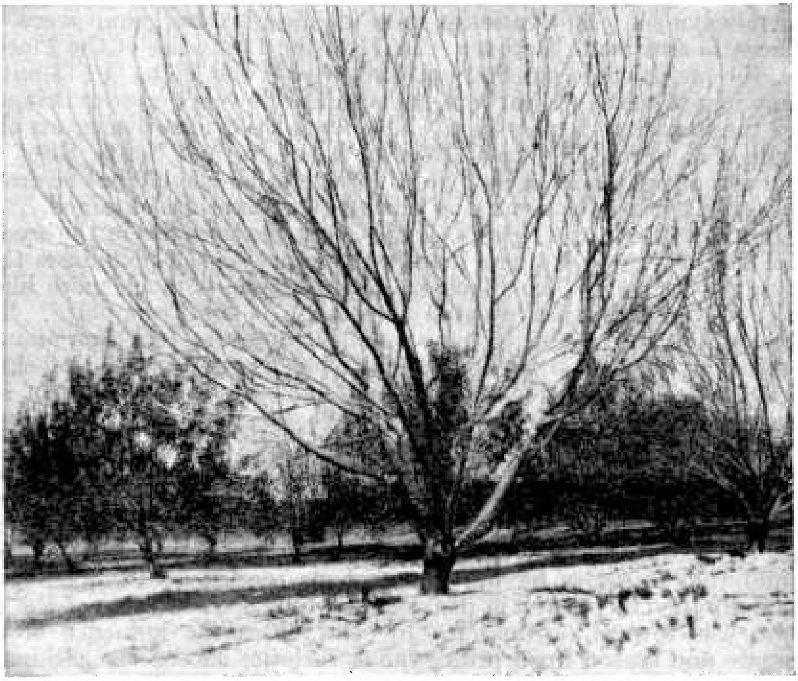

FIGURE 10.—Mayette walnut tree in the foreground; Eureka trees in the background. At the time the picture was taken the Eureka trees had ceased to shed pollen. When the Mayette trees developed catkins the Eureka pistils were past the receptive stage, therefore there was no interpollination between the Eureka (an intermediate bloomer) and the Mayette (a late hloomer). In some seasons, however, there is a considerahle exchange of pollen hetween these two varieties.

some varieties tend to bloom earlier than others under the same conditions (figs. 10 and 11). An examination of figures 7 and 8 will make it clear that for any given district certain varieties are comparatively late bloomers, whereas others are early bloomers. Another group consists of intermediate bloomers, which lap over somewhat into the blooming period of either the early or the late bloomers. The period of bloom of the intermediate varieties is usually closer to that of the early bloomers than to that of the late bloomers. Table 6 gives this grouping in a form convenient for reference.

INFLUENCE OF SEASON ON BLOOMING DATES

Although varieties are reasonably consistent in their time of bloom in relation to one another, the date of bloom, length of blooming period, and blooming habit are greatly affected from year to year by the variations in the seasons. The dates on which a variety may

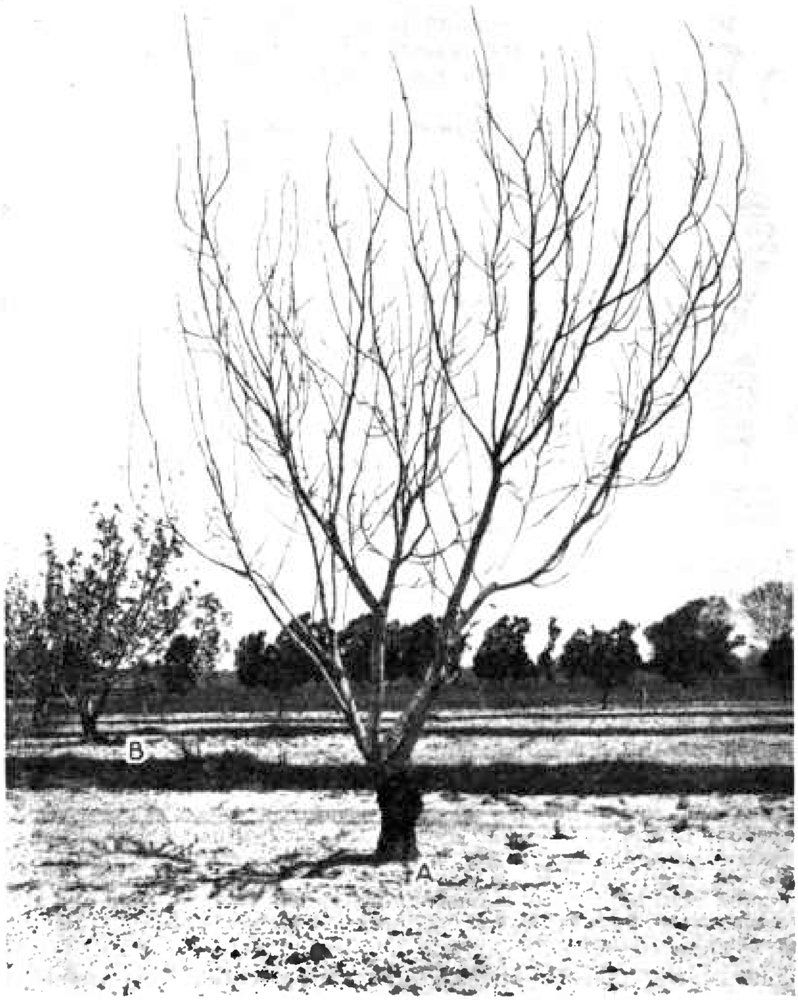

FIGURE 11.—Blooming habit of three varieties of walnut trees: *A*, Meylan, upon which a few buds are beginning to open; *B*, Eureka, which is just finishing its pollen-shedding period; in the background, Payne, which ceased to shed pollen before the Eureka tree began to bloom. The late pistils on the Payne received some pollen from the Eureka, and a few days after this picture was taken the late Eureka pistils received some pollen from the early Meylan catkins. The Meylan pistils received no pollen from the Eureka, and the Eureka received none from the Payne, owing to the protandrous blooming habit of the three varieties during the season. (All the trees are of the same age.)

bloom in a given district may differ by a month or more. Similarly, the length of the blooming period may vary from a few days to two and one half months. The rate of blooming may be very slow, a few new blossoms maturing each day, or it may be rapid, many blossoms developing at the same time. Continuous cold weather in late winter and early spring delays blooming; continuous warm weather hastens it. Any warm sunny spell immediately preceding or occurring during the normal blooming period of a variety will start the bloom, its rapidity and length depending on the degree and duration of the warm weather. If the contrast is sharp between the warm spell and the weather that preceded it, blooming is sudden and rapid. A cold spell during the blooming period retards and protracts it. A comparative study of the seasons of 1922 and 1924 will serve to illustrate these points. (See figs. 7 and 9.)

TABLE 6.—*Early, intermediate, and late-blooming walnuts* [1]

Early blooming	Intermediate blooming	Late blooming
El Monte.	Concord.	Franquette.
Ehrhardt.	Eureka.	Frostfighter.
Golden Nugget.	Japanese.	San Jose.
Grove.	Some strains of Hinds.	XXX Mayette.
Kaghazi.	Bijou type.	Meylan.
Lucretia.[2]		Willson.[3]
Mayette (Early Blooming).		Mayette (Grenoble).
Payne.		Parisienne.
Placentia.		Some strains of Hinds.
Praeparturiens.		
Pride of Ventura.		
Santa Barbara soft-shell types:		
Santa Rosa.		
Wasson.		

[1] For further information on these varieties, see List of Varieties, p. 50.
[2] Data collected for 2 years only.
[3] In some sections Willson is one of the earliest bloomers in this group.

It will be noted that the Payne at Linden, the Golden Nugget, El Monte, and Santa Barbara at Modesto, and the Payne, Kaghazi, and Praeparturiens at Oakdale all bloomed from 20 to 30 days later in 1922 than in 1924. (See fig. 7.) The Franquette at Linden, which bloomed at more nearly corresponding dates in 1922 and 1924, furnished the only exception among the cases where information is available for comparing the behavior of varieties in those 2 years. The United States Weather Bureau reports (*12*) for 1922 read in part as follows:

> Abnormally cold weather prevailed throughout California in January. * * * It was the coldest February in 11 years. * * * Abnormally cold weather prevailed during the greater part of March. The average temperature of the State was more than 3° below normal. * * * The temperature and precipitation were both below normal during April. * * * Cold and cloudy weather prevailed during the first half of the month; the latter half of the month was somewhat warmer.

The nearest place to the walnut-growing section mentioned (that of Linden, Modesto, and Oakdale) at which weather records are kept is Stockton. A study of the records shows that this general description of California weather for 1922 was applicable there except that a very short warm period occurred during the first week of April. This was followed by cold and then by a second warm period at the end of April. In this cold season the blooming of the early varieties was delayed. The behavior of the Franquette now becomes intelligible. It is a late-blooming variety, and the warm weather began close to its normal blooming time, with the result that its blooming period was not delayed.

On the other hand, in 1924 the opposite condition prevailed. To quote from the reports of the Weather Bureau (*12*):

> In February the temperature averaged well above normal. Considering the entire State, it was the warmest February since 1907. The latter part of the month was especially warm. * * * The first half of the month [March] was unusually warm and dry, but the second half was cold. * * * [In April] temperatures averaged slightly above normal. They were considerably above normal at many places in the northern part of the State. * * *

This description was found to be applicable to the weather at Stockton in that season. Thus, in 1924 abnormally warm weather in February and March brought out the bloom of the early varieties about a month sooner than in 1922. A cold spell at the end of March protracted the blooming and checked its rate, so that the total period of bloom of pistils and catkins was longer in 1924 than in 1922.

All seasons are not so easily compared as these two rather striking examples, but it will be found that during each year varying successions of weather, combined with the natural tendency of the variety, serve to fix the date of bloom at one point or another within a period of 5 or 6 weeks.

It will be noted in the figures that in general early-blooming varieties vary more in length and date of bloom than late ones. This is probably because of the fact that in early spring when the early varieties tend to bloom the weather is more changeable than later on.

INFLUENCE OF CLIMATE ON BLOOMING DATES

While all the districts in California in which walnuts are grown possess what is generally termed a mild climate, they vary considerably in the type of climate. The districts may be classified for convenience as coastal and interior. The former have a climate characterized by mild winters, cool summers, and on the whole a humid atmosphere with frequent fogs. The temperature ranges between winter and summer are less on the coast than in the interior, the winters being milder and the springs and summers cooler. On the coast the mildness of winter increases toward the south. According to the Weather Bureau, the coastal area extending from Los Angeles to San Diego has the most equable climate in the United States. Of the districts in which studies were made (figs. 7, 8, and 12) the following may be classified as coastal, beginning at the south and going north: Areas near San Diego, San Juan Capistrano, Santa Ana, Los Angeles, Oxnard, Ventura, Santa Barbara, San Luis Obispo, Paso Robles, King City, and San Jose.

In contrast with that of the coast, the climate of the interior valleys of California is characterized by comparatively cold winters, warm springs, and hot summers. Sunshine is abundant, and hot drying winds may occur during spring and summer. This type of climate prevails at Red Bluff, Chico, Orland, and Riverside.

There are all gradations between the typically interior and typically coastal climates. The topography may allow coastal influences to extend inland to a greater or less degree, depending on the distance of a locality from the ocean, height and number of intervening hills or mountain ranges, and the direction and velocity of the wind. Likewise, coastal districts may be protected by features of topography in such a way that the climate is modified. Modesto, Stockton, Linden, Sacramento, Davis, Waterford, and San Fernando may be considered as interior districts receiving coastal influences in various degrees. San Jose, King City, Paso Robles, Fillmore, Moorpark, and localities lying just east of Los Angeles, also some of the valleys in San Diego County are coastal districts more or less protected (fig. 12). In

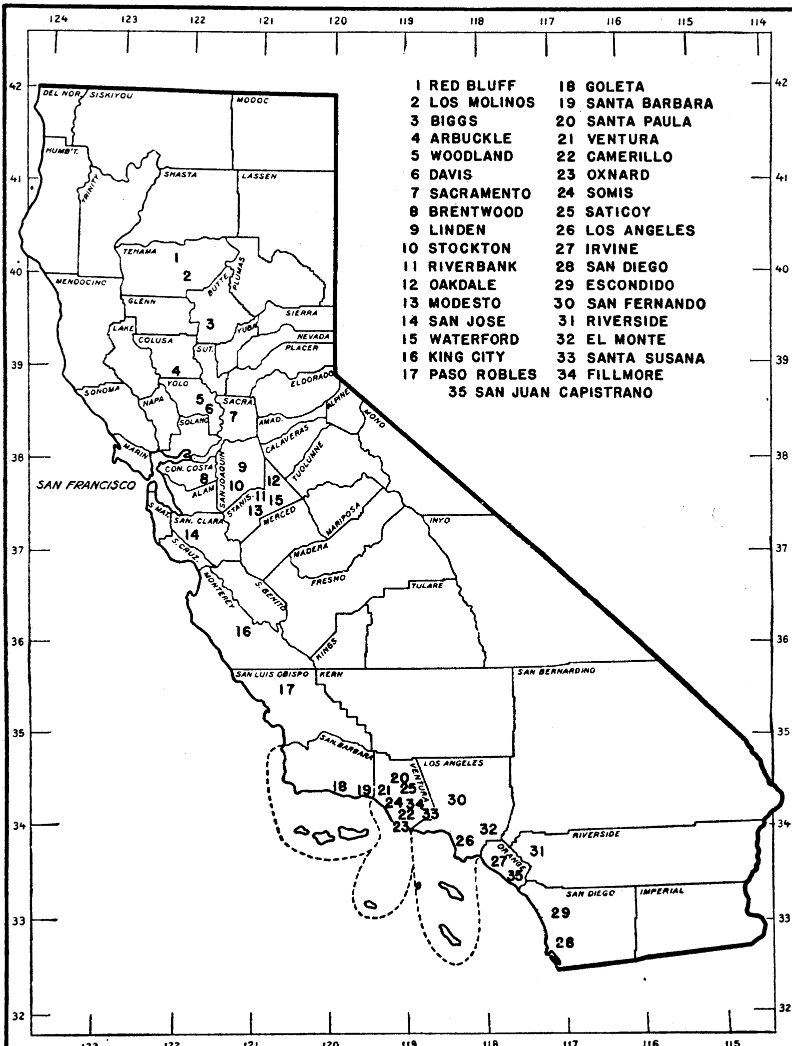

FIGURE 12.—Map showing localities of the California walnut-growing districts where most of the work was done.

many cases the line of demarcation is so narrow as to make classification difficult.

In California a difference in latitude does not result in the degree of variation in climate that might be expected. Instead of running east and west, as in most other parts of the United States, isothermal lines run north and south. A slight difference in location in an easterly and westerly direction is reflected appreciably in the climate, while a much greater difference in a northerly and southerly direction is hardly noticeable. Red Bluff in the north of the State and Riverside in the south, both of which are in the interior, have climates that are similar, although the difference in latitude of the two places is equivalent to 400 miles (fig. 12). On the coast the climate varies with the latitude to a greater degree than in the interior valleys, although the variation is slight. Farther north the winters are somewhat more severe.

The influence of the various climates upon the blooming habit of the walnut is marked. The varieties bloom earlier and for a shorter period in the interior than on the coast. Figures 7 and 8 show that the Franquette and other late varieties bloomed in the San Joaquin and Sacramento Valleys in the latter part of April and in May at the same time that such early varieties as the Placentia, El Monte, and Santa Barbara were in bloom at Ventura and in other southern coastal districts. As the Franquette seldom blooms at Ventura earlier than July, the nuts do not have time to develop and mature properly. For this reason late-blooming varieties are not successful in southern coastal sections. Early varieties bloom there as late as is desirable. On the other hand, late varieties are suitable for the interior valleys, where early varieties are apt to be injured by spring frosts. At Ventura winters are usually so mild that walnut trees frequently do not pass through a normal dormant period, or, at least, the period of complete dormancy is very short. The winters are usually followed by mild cool springs. In such a climate a protracted blooming period is the rule. At San Jose, which lies in a latitude approximately 200 miles north of Ventura and is slightly more protected from ocean winds, the climate is colder in winter, and there is a greater difference between winter and spring.[7]

Temperature tables of the Weather Bureau show that Santa Barbara, a few miles north of Ventura,[8] is warmer in January, February, and March than is San Jose, but that San Jose is warmer than Santa Barbara in May and June and usually in April. At San Jose the comparatively warm springs following cold weather make the blooming period earlier and shorter than on the southern coast. Consequently, the Franquette, San Jose, and other late-blooming varieties can be grown there successfully. Early varieties at San Jose are subject to frost injury during blooming time, although not so much so as in the interior. In the interior valleys the winters are still colder, but the springs are comparatively warmer. Dormancy is marked, and the varieties in general bloom earlier, more rapidly, and for a shorter period.

EFFECT OF CLIMATE, SEASON, AND WEATHER ON DICHOGAMY

Climate, season, and weather have a pronounced effect upon the length of the overlap in blooming of the pistillate and staminate flowers. For some reason the latter seem to respond more quickly

[7] According to weather reports covering a long series of years, the average difference in winter temperatures at Santa Barbara and San Jose is 5° and the average difference in spring temperatures is 1°. The average difference between winter and spring temperatures at Santa Barbara is only 3° and at San Jose 7°.

[8] Weather records at Santa Barbara are mentioned here and are included in the tables because it is one of the nearest places to Ventura at which Government weather records are kept. No such records are available for Ventura.

to sudden periods of warm weather than do the former. The contrast between their behavior is greater when the change of weather is sudden than when it is gradual. During a warm period following a cold winter there is a tendency for growth to be rapid in all parts of the tree, but the effect of such a change is especially marked upon the staminate flowers. When the warm weather continues for a number of days the staminate flowers may develop so much faster than the pistillate flowers that, in varieties having protandrous tendencies, the blooming of the former may be entirely over before that of the latter has begun, i.e., dichogamy may be complete. Warm weather following cold increases protandry and modifies protogyny. When, after a warm winter, the weather during the blooming season is cool, protogynous tendencies in the varieties are accentuated, and protandrous tendencies are modified.

So great may be the effect of weather and climate that a variety in which the tendency on the whole is protogynous may appear at some places and in some seasons to be protandrous (fig. 13), and in the same way a variety that is protandrous may appear on occasion to be protogynous.

To illustrate, the Santa Barbara group, which is protogynous at Ventura, was slightly protandrous at Modesto in 1922. The trees bloomed later than usual on account of the coldness of the season. The staminate flowers came out quickly after a brief warm period in early April, the preceding weather having been consistently cold. The Willson variety normally blooms later than the Santa Barbara and appears protandrous in most cases. In 1922 at Modesto the Willson catkins had not yet come out in response to the first warm weather when a cool period ensued. During this cool interval the Willson pistils began to bloom at about their normal time, making that variety appear protogynous. In a second warm period, during which the daily temperatures were high, the Willson catkins bloomed so rapidly as to complete their bloom six days before the last of the pistils appeared. Thus, the Willson seemed protogynous at the beginning of the season and protandrous at the end, as a result of weather conditions. The Placentia catkins preceded the pistils at Linden in 1927, at places east of Fillmore in 1928, and at King City in 1929. When charts show the Placentia and Santa Barbara catkins coming before the pistils, it is in districts where the coastal climate is modified or the climate verges on the interior type. At Modesto the El Monte pistils came out in advance of the catkins in 1923, 1924, and 1927, but otherwise the variety appeared protandrous. Many examples of both types of variation could be cited. Groups of Eureka, Franquette, Concord, and Payne trees were found to exhibit protogynous tendencies in coastal districts in some seasons. These are not shown because the records were incomplete in one way or another. These varieties are not grown to any extent in southern coastal districts, and it is difficult to obtain comprehensive data regarding their behavior there. The same difficulty was experienced with protogynous varieties not commonly grown in the interior.

As heretofore stated, a slight change in location in an easterly or westerly direction often results in an appreciable change in climate. These changes affect the blooming dates and the character of the dichogamy in walnut varieties. Records taken in 1928 show the extent to which this is true. Table 7 is a summary of observations

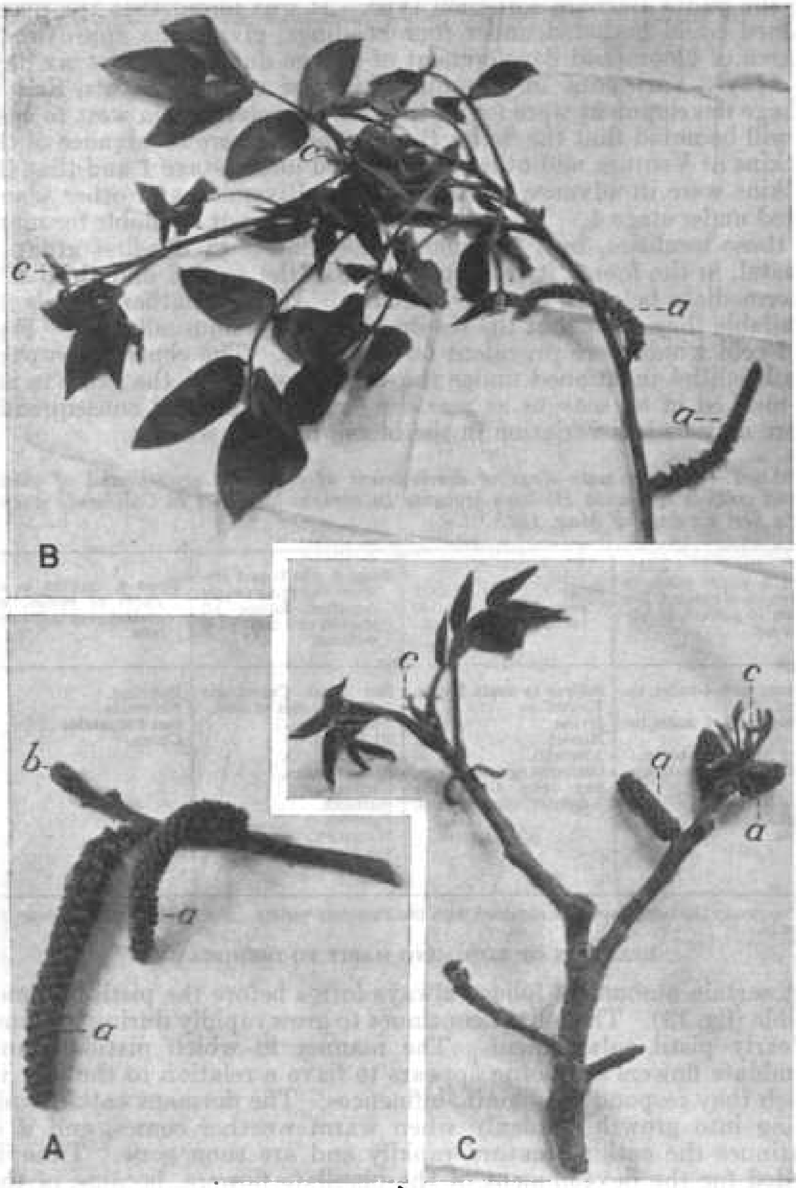

FIGURE 13.—Typical twigs of Placentia walnut, illustrating three marked variations in the types of dichogamy in a variety, due to climate. *A*, Twig from an orchard near Simi, illustrating protandry. The staminate flowers (*a*) are beginning to shed pollen, and the foliage bud (*b*) is just swelling. Before the pistils are produced terminally on the shoot which will spring from the bud (*b*) the catkins will be gone. *B*, Twig from Placentia tree near Fillmore (where the climate is somewhat more coastal in effect than at Simi), showing catkins (*a*) shedding pollen at the same time the pistils (*c*) are receptive. The Placentia variety in this orchard pollinated itself satisfactorily during the season. *C*, Twig from an orchard near Ventura (which possesses a distinctly coastal climate), showing protogyny. The pistils (*c*) have been receptive for a considerable time. The catkins (*a*) are enlarging, but the pistils will be past receptiveness before any pollen is shed. The climate and weather conditions which brought about these variations in the localities mentioned were marked during 1928.

on the Santa Barbara soft-shell type. It was found that the places named could be listed under four headings, giving the approximate degree of bloom and development of foliage during the first six days of May. Variations in blooming dates of catkins, pistils, and in foliage development were found to occur especially from west to east. It will be noted that the Santa Barbara pistils were in advance of the catkins at Ventura and other places listed under stage 1 and that the catkins were in advance of the pistils at Riverside and other places listed under stage 4. Temperature records are not available for many of these localities, but, in general, the climate in the first group is coastal, in the fourth it is interior, and in the second and third it is intermediate between the two extremes. Where weather records are available they show that the season of 1928 was unusually cool. Fogs and cold winds were prevalent on the coast. The contrast between the localities mentioned under the various stages in the table is not as marked in all seasons as was the case in 1928, and consequently there may be less variation in the bloom in some seasons.

TABLE 7.—*Approximate stage of development of vegetative growth and of pistils and catkins of Santa Barbara walnuts in various localities in California during the first six days of May, 1928* [1]

Stage 1, pistils much in advance of catkins; less than 10 percent of foliage out	Stage 2, pistils slightly preceding catkins; 50 percent of foliage out	Stage 3, pistils and stamens blooming nearly together; foliage all started and most of it well out	Stage 4, catkins in advance of pistils, but overlapping to some extent
Ventura and 4 miles inland. Oxnard and 4 miles inland. Santa Ana to the ocean. Coast of San Diego County. Santa Barbara. Carpinteria Goleta.	Saticoy to Santa Paula. Escondido. Irvine. Rincon. Anaheim. Orchards east of Goleta. San Juan Capistrano district, near the coast.	San Juan Capistrano district, east of hills. Puente. El Monte. Walnut. Santa Susana. Glendale. Burbank. Fillmore. Moorpark. San Jose. Gilroy.	Banning. Riverside. San Fernando. Chino.

[1] Practically the same data were obtained with the Placentia variety. For location of these places, see figure 12.

RELATION OF BLOOMING HABIT TO DICHOGAMY

A certain amount of foliage always forms before the pistil becomes visible (fig. 13). The foliage continues to grow rapidly during the time of early pistil enlargement. The manner in which pistillate and staminate flowers are borne appears to have a relation to the way in which they respond to climatic influences. The dormant catkin buds spring into growth suddenly when warm weather comes, and if it continues the catkins mature rapidly and are soon gone. Time is needed for the development of the pistillate flowers, because of the amount of growth that must take place before the pistils reach the receptive stage. When the weather becomes warm suddenly, as it frequently does in the interior valleys, the blooming of the catkins may be over before the pistils have time to mature; on the other hand, the foliage buds may start with a slight warming up in the spring and continue to grow even though the weather is comparatively cool. In a climate such as generally prevails along the coast the pistillate flowers may develop fully while the catkins are awaiting weather warm enough to stimulate them into growth.

The relative amount of heat necessary to start pistillate and staminate flowers into bloom appears to be a varietal characteristic.

EFFECT OF TEMPERATURE ON BLOOMING AND DICHOGAMY

A certain amount of warmth and sunshine is necessary to bring walnuts into bloom. When temperature charts were studied it was found that the mean or minimum temperatures had less relation to date of bloom than might be expected. A relation between maximum daily temperatures and date of bloom was apparent, but not entirely regular. No definite heat constant could be established for the maximum daily temperatures that would be sufficient in all cases to bring about the blooming of a variety. In Germany, observations on the effect of heat and sunshine on the time of blooming of many plants were made by Kerner (*6*) over a long period. He emphasizes the importance of sun rather than shade temperatures in determining the amount of heat necessary to bring about flowering. As sun-temperature records are not available in California, a critical study of the relation of sun temperatures to development of flowers of walnuts was not made. Such temperature studies as were made indicated no definite relation between total heat units and time of blossoming in the different varieties.

The striking fact derived from these temperature studies is that the temperature records as commonly kept are less valuable in indicating the date and length of bloom than might be expected, and that sunlight may have a marked influence on date and length of bloom. Conversely, the importance of fogs and clouds is very great. Temperature, sunlight, fogs, winds, and atmospheric moisture all affect the blooming period of the walnut. It is also possible that lack of complete winter dormancy may retard blossoming in the coastal districts having relatively high winter temperatures. Though it may be possible at some future time to express the effects of all these agencies in terms of temperature units, it is not now possible to do so with the information available.

RELATION OF LONG AND SHORT PERIODS OF BLOOM TO POLLINATION AND DICHOGAMY

It has been shown that overlapping of blooming of stamens and pistils is an important consideration for self-pollination, and that conditions which bring about rapid blooming may result in a degree of dichogamy sufficient to prevent adequate pollination. On first consideration it would seem that the more protracted the blooming season, and more particularly the longer the overlapping of the bloom of the two types of inflorescence, the better the chance for self-pollination, but this is not necessarily the case. The conditions that cause a very long blooming season are often such as to prevent pollination from taking place. For example, the season at Ventura for 1928 was exceedingly protracted. Figure 7 shows that the blooming season of the Placentia that year was longer than for any other year indicated, although the district generally has long blooming seasons. The period of adequate overlapping bloom lasted 19 days, yet the Placentia crop that year in the district was light. Figure 7 shows that the Placentia stigmas were receptive for 24 days before any catkins began to shed pollen, and for 18 days more only a few catkins were produced. Thus, for 42 days the stigmas were not pollinated to any extent. From May 11 to 30, inclusive, the catkins were shedding pollen, and the stigmas were receptive in sufficient numbers to account for a commercial crop if other conditions had been favorable, but this was not the case. The period was one of cold and foggy weather. Much of the pollen that was shed from the anthers was injured by being soaked with moisture from fogs. On many days fogs in the forenoon were followed by such cold winds in the afternoon that the anthers did not shed pollen. Therefore, although receptive stigmas were present for a longer period than usual, pollination was slight.

In such long blooming periods it appears that most of the pollination is accomplished during a few days of favorable weather, but that a day of good weather is much less effective than in a short blooming season because fewer stigmas are in a receptive stage and fewer catkins are shedding pollen.

The blooming season for 1929 at Ventura was earlier and shorter than that of 1928. Effective self-pollination of the Placentia could occur only during a 9-day period (April 25 to May 3), but the weather was favorable, and the Placentia trees produced good crops even in orchards where cross-pollination was not possible.

In orchards in which both the Placentia and Santa Barbara walnuts are grown, it will be seen (fig. 7) that during 1928 the Placentia should have been either self-pollinated or cross-pollinated from May 1 to 23, a period of 23 days, and the Santa Barbara trees should have been either self-pollinated or cross-pollinated during a 15-day period extending from May 1 to 15. During 1929 efficient cross-pollination could have taken place for the Placentia and Santa Barbara walnut orchards only from April 23 to May 3, an 11-day period. During most of this period, however, the weather was warm and sunny, and winds blew nearly every day. During such weather catkin development was rapid; numerous pistils with receptive stigmas were ready to receive the pollen, which was efficiently distributed by wind. The result was evident in the heavy crop in the Ventura district in 1929, as against a light crop in 1928.

INTERPLANTING OF VARIETIES FOR POLLINATION PURPOSES

Since single varieties do not always pollinate themselves satisfactorily, the pressing question from the standpoint of growers is, What varieties should be interplanted to assure cross-pollination? As yet the question cannot be answered authoritatively for every variety or for every district. It has been shown that varieties are not alike in their response to climate and weather, that the districts differ from one another in climatic influences, and that there is considerable variation in seasons. It has not been possible to conduct observations in every district each year, and some varieties have not yet been studied. Moreover, all combinations of varieties are not to be found in all districts for purposes of comparative study. Nevertheless, the data at hand should make it possible to select combinations of varieties for interplanting that will greatly improve the chances for adequate pollination, even though there is no certainty that the varieties selected will pollinate each other perfectly in all seasons.

A study shows that for a number of days in nearly every year pistillate flowers of each variety are blooming and fading in large numbers, with no possibility of being pollinated by trees of the same variety. These unpollinated pistillate flowers represent the potential increase in walnut crops when adequate provision is made for interpollination. Almost any combination of varieties is likely to increase pollination to some extent, and even a few extra days of pollination may make the difference between a large and a small crop and between profit and loss in the management of an orchard.

It would seem that the ideal arrangement would be to plant protandrous varieties with protogynous varieties blooming at the same time, so that they will pollinate each other. However, the modifications of protandry and protogyny according to weather and climate are such that it is difficult to say just what will happen in any district with such combinations of varieties. The Payne (protandrous) has been planted with the Placentia (protogynous) in some places. At Linden in 1927 the Placentia was protandrous. It bloomed so as to increase the pollination of the Payne, but received no benefit itself from the combination. At King City in 1929 the Placentia pistils and catkins bloomed together. The Payne was completely dichogamous, but was pollinated by the Placentia. In this case the combination was very helpful. Records obtained during 1928 and 1929 indicate that a new variety, the Lucretia, is a good pollinizer for the Payne. It seems to produce catkins at the proper time to pollinate the Payne pistils and appears to be protogynous in tendency. A further study of protogynous varieties may make it possible to select varieties of opposite types for each district, but this cannot be done at present.

The planting together of a number of varieties gives the best chance for the pollination of all the trees in an orchard, but some groupings are more likely to be effective than others. When early-blooming varieties are interplanted they may all suffer from the same pollination trouble at the same time, or each may help some other for a few days and increase the total pollination appreciably. There is more variation in the time of bloom of the early than of the late varieties, and, therefore, better results are likely to be obtained from interplanting them than from interplanting varieties belonging to the late group. If the behavior of the Payne, Praeparturiens, and Kaghazi (early varieties) at Oakdale in 1922, 1923, and 1924 is studied it will be found that in 1922 almost nothing was gained in extra pollination by this combination of varieties. In 1924 the Kaghazi pollinated the Payne pistils for 5 days beyond the period of self-pollination. The Praeparturiens provided 7 days of extra pollination for the Payne and 2 days of extra pollination for the Kaghazi. The Praeparturiens itself bloomed unpollinated for a long period, as it was the latest bloomer in a group of varieties, all of which were protandrous in tendency. In 1923 the benefit of interplanting to the Payne was very marked. In that year and locality all of the Payne pollen had been shed before the stigmas were receptive, but the Kaghazi and Praeparturiens supplied pollen to the Payne throughout almost the entire period of its pistillate bloom. In general it may be said that groups of early-blooming varieties will have a longer period of effective pollination than will any one variety in the group, and that interplanting is helpful, although not always entirely satisfactory.

In the same way late varieties will help one another, although to a lesser extent. The Franquette is often useful in furnishing pollen for certain other late varieties, but it rarely receives benefit itself in the way of pollen from other varieties. For example, the San Jose at Linden in 1929 bloomed with the Franquette. Both were practically dichogamous, and neither helped the other. In 1922, however, at Oakdale, the San Jose (which was dichogamous in this year, also) was much benefited by the Franquette, though the Franquette received no help from the combination. It is difficult to find suitable pollinizers for the Franquette, which is one of the last varieties to bloom and is decidedly protandrous. Protogynous varieties blooming at the same time would seem to present the ideal combination, but it is probable that protogynous tendencies would be overcome by climatic influences in some of the districts where the Franquette is grown most successfully. The Meylan, which is a late bloomer and is somewhat protogynous in most districts, seems to be of considerable promise as a pollinizer for the Franquette and should be tried out fully in all districts. Sometimes the Hinds will help to pollinate the Franquette, but the strains must be selected carefully. The Willson is helpful in some districts. The Parisienne might be helpful were it not for the fact that the variety does not bear catkins regularly. The Frostfighter, which has been under observation for a few years in the San Jose district, seems to produce pollen in large quantities at the right time to pollinate the Franquette. Its nut is not valuable commercially, but it ripens so late that it is easily kept separate from the Franquette during harvesting. It may prove on further testing to be of great value for pollinating the late-blooming group.

In any combination consisting of protandrous varieties the latest blooming variety in the group suffers most because many of the pistils may come out after the pollen from all the varieties is shed (figs. 10 and 11).

When early and late varieties are interplanted they frequently bloom so far apart that the blooming periods do not overlap (fig. 11). In some seasons, however, the blooming periods are brought close together, and under these circumstances cross-pollination may take place. Combinations of early and late varieties are not usually entirely satisfactory unless planted with intermediate blooming varieties.

Probably the best combinations of varieties are those that bring together early and intermediate bloomers, or intermediate and late bloomers (see table 6), or all three. In these cases the latest bloomer may not be pollinated adequately in all seasons, but will help to pollinate the rest. To illustrate, figure 7 shows that at Oakdale in 1920 the Payne (an early bloomer) was not adequately self-pollinated, but would have been fully provided for by the Concord (intermediate bloomer), which was self-pollinated. At Linden in 1925 the Eureka (intermediate blooming) and the Franquette (late blooming) would have provided pollen for all the pistils of the Early Blooming Mayette and the Payne (both early-blooming varieties). In that year the Mayette was almost completely dichogamous. The Franquette in the same season would have added effectively to the pollination of the San Jose and the Willson (late-blooming varieties). Many other illustrations could be given. The charts shown as figures 7 and 8 are the best guide at present to the probable effect of planting the various combinations of varieties. The grower should study his own district particularly.

In orchards in various parts of California combinations of varieties can be found which appear to have resulted in great benefit from a pollination standpoint. In the southern California coastal regions the Placentia and Santa Barbara during most seasons receive mutual benefit when interplanted. In coastal districts Pride of Ventura, Wasson, Placentia, and Santa Barbara are sometimes found in the same orchard, and in such orchards pollination is usually excellent. In the interior valleys plantings consisting of any three of the four varieties, Payne, Placentia, Concord, and Eureka, result in great improvement from a pollination standpoint over any one of the varieties planted singly.

Some growers have gone to the extreme in planting a large number of varieties. One orchard in the Waterford district consists of the following varieties: El Monte, Payne, Concord, Eureka, San Jose, XXX Mayette, Meylan, Franquette, and a few seedling trees. In this orchard two or more varieties are shedding pollen during the entire blooming season, with the exception perhaps of a very few days at the beginning. An orchard in the Modesto district has the following varieties: El Monte, Golden Nugget, Concord, Eureka, XXX Mayette, Willson, and Franquette. An orchard in the Oakdale district contains Kaghazi, Praeparturiens, Payne, Concord, Eureka, Mayquette, Mayette, San Jose, Franquette, Parisienne, and Willson varieties. In the Santa Clara Valley one orchard consists of trees of Santa Rosa, Payne, and Franquette varieties of the Persian walnut and also several trees each of Japanese walnut and Persian walnut seedlings. In these orchards pollination is well provided for, but more varieties are included than should be necessary.

It must be remembered that cross-pollination is beneficial not only in providing protection when dichogamy is complete but in increasing the number of pistils pollinated in seasons when some degree of self-pollination occurs. Growers need not plant great numbers of inferior varieties, but until further data are available, it might be wise to plant good pollinizers sparingly as crop insurance for the better varieties,[9] even though they do not necessarily produce high-grade nuts. It is hoped that eventually dependable combinations for all walnut-growing districts can be listed. In the meantime, although ideal combinations for all seasons and localities are not easily arranged, the following general recommendations for planting should be helpful. First, the grower should select the main variety desired for his orchard. He should next select at least one other which blooms about the same time, and, if the main variety is protandrous, one or two other that bloom a little later. If there is a possibility that the main variety may be protogynous in the district, he should plant one other that blooms earlier. It should be borne in mind that many of the stigmas of the earliest variety in the orchard are likely to go unpollinated if the variety is protogynous and that many of the stigmas of the latest variety are likely to go unpollinated if that variety is protandrous.

It appears from the studies that great benefit will result from proper provision for pollination in walnut orchards. The ideal to be attained is that abundant pollen shall be available throughout the period during which stigmas of any of the varieties are receptive. Such an arrangement will increase the opportunity for a heavy set of nuts without increasing the cost of production.

[9] The distance pollen is carried by the wind is discussed on p. 44.

MISCELLANEOUS POLLINATION FACTORS AFFECTING THE SETTING OF NUTS

In previous sections of this bulletin it has been shown that when not dichogamous, all of the walnut varieties studied are both self-fertile and interfertile. Such a condition is favorable to nut production. It has also been shown that the existence of dichogamy often prevents satisfactory self-pollination and sometimes interferes with cross-pollination. Dichogamous tendencies in walnut varieties are, therefore, unfavorable to nut production. Aside from self-fertility and dichogamy, the following important factors in relation to pollination determine whether nuts will set: (1) Viability of pollen; (2) amount of pollen produced; (3) efficiency of distribution; (4) length of period of pollen production; (5) number of pistils produced; (6) size of pistil when receiving pollen; and (7) length of period of pistil receptivity.

VIABILITY OF WALNUT POLLEN

Whether pollination is accomplished artificially or takes place by natural methods, it is necessary that some of the grains reaching the stigma be viable if fertilization of the ovules is to take place. All of the pollen specimens used in artificial pollination work and many other specimens of pollen taken from trees in the field were tested for viability. The specimens of pollen taken from trees in the field were tested for viability. The specimens were subjected to germination tests and to microscopic examination for the determination of protoplasmic contents. Especial attention was given to 18 varieties of Persian walnut pollen, to pollen obtained from various strains of Hinds, of the California black walnut, of the eastern black walnut (*Juglans nigra*), and of the Japanese walnut.

Great variation in the percentages of viability of the pollen was found in the specimens examined. In many cases it was exceedingly low, and microscopic examination showed a large proportion of grains to be devoid of protoplasmic contents. Many of the grains appearing normal failed to germinate. The percentage of viability of the pollen specimens tested varied from 0 to 80 percent, the average being 23 percent. While there was much variation in different specimens of each variety, some varieties appeared habitually to produce a larger proportion of viable grains than others. Certain varieties, of which the Golden Nugget and particular trees of the Santa Barbara type are examples, produced a larger percentage of abnormal grains than did the Eureka, Franquette, or XXX Mayette. The viability of pollen grains varied with the season, locality, and general climatic condition. The factors affecting viability are not well understood, but it is possible that viability depends in some way upon the rapidity of development of pollen in the anthers. It also appears that sunshine is beneficial to the production of viable pollen. It is clear that rains and heavy fogs at the time pollen grains are being shed by the anthers cause deterioration. Pollen grains after having once been wet are usually found to have lost their viability.

The age of pollen grains bears a marked relation to their viability. In general it may be said that the older the grains the lower the percentage of normal grains and the lower the viability. After the pollen is scattered in the field its viability decreases rapidly. It seems that under average field conditions walnut pollen grains remain viable for only a few days at most after being shed from the anthers. The period of viability of pollen grains may be considerably prolonged by storing under proper conditions. After experiments had been conducted in storing pollen in a large number of ways, it was found that the grains retained their viability best when the pollen was kept in glass vials stoppered with cotton and containing a small piece of catkin to supply a slight amount of moisture to the air in the vial. A cool dry place was found to be most favorable for storage. In many instances walnut pollen kept in this manner had enough viable grains at the end of 3 or 4 weeks to warrant its use in artificial pollination experiments. In some instances, however, pollen kept under the most favorable conditions known to the writer was devoid of viability after 2 weeks. When exposed directly to the air, the grains retained viability for only a few days at most. Many growers have thought that pollen remaining upon the branches or foliage would be efficacious for a considerable time in fertilizing the pistils. It is probable that such pollen is not important in the commercial production of nuts, since it would not remain viable for any length of time when exposed to the air.

That the tests show an average of only 23 percent of viable grains of walnut pollen in the fresh specimens examined is significant, because over four times as many grains must be distributed to result in fertilizing the same number of ovules as would be fertilized if all the grains were normal.

AMOUNT OF POLLEN PRODUCED

Because the walnut depends upon wind for the distribution of pollen, a great deal of waste takes place, as is the case with all anemophilous plants. The number of catkins produced by a variety and the quantity of pollen shed per catkin at the time the stigmas are receptive have a direct relation to nut production and also determine the number of trees necessary for interplanting among dichogamous varieties. In order to arrive at an estimate of the quantity of pollen produced the catkins were counted on various trees and as much pollen as possible was collected from individual catkins, the grains being counted under the microscope. The grains were collected from the catkins as follows: Several prepared microscopic slides were fastened edge to edge on heavy cardboard, so as to make a continuous glass surface. This plate was placed directly under a single catkin and held horizontally in place about 2 inches below the catkin by means of wire frames fastened to the branch. Shields of heavy manila paper were placed around the catkin and the prepared plate to serve as a protection from air currents. The plates were replaced as often as necessary until the catkin ceased shedding pollen. The slides were then separated and the pollen grains counted under the microscope.

Another method used consisted in cutting out measured sections of catkins. Pollen was shaken out of these sections from time to time as drying took place, and the number of grains obtained was used as a basis for calculating the numbers of pollen grains produced by the entire catkin.

It is clear that in each method some of the pollen was lost. Nevertheless, it was found that single catkins produced from 1,000,000 to 4,000,000 pollen grains.

Upon some of the larger Placentia trees as many as 10,000 catkins were counted during a season. Seldom did large trees produce fewer than 500 catkins. In one old orchard catkins produced by single trees ranged in number from 1,500 to 11,000, the average being approximately 5,000. It will be seen that there was a probability of individual trees in this orchard producing from 1,500,000,000 to 40,000,000,000 pollen grains. One tree of average type would, therefore, produce enough pollen grains to pollinate several acres of walnut trees, provided all conditions were perfect. It is certain, however, that perfect conditions never exist. The viability of pollen is often low; many catkins are commonly destroyed or damaged by frosts, rains, fogs, insects, or diseases, and there is great waste in the distribution of pollen grains. Fewer catkins are produced on young than on old trees, and in some varieties such as Parisienne very few catkins are produced at any age.

POLLEN DISTRIBUTION

Walnut pollen grains are extremely small, averaging 46 microns in diameter.[10] While other workers have found that pollen grains of certain species of coniferous trees have been carried by wind for distances of several miles, it should not be assumed that walnut-pollen grains will likewise be transported such distances by wind. Coniferous-pollen grains are not only exceedingly small in size but possess air sacks which enable them to float in the air. Walnut-pollen grains, although small, have no air sacks and therefore settle slowly to the ground.

Experiments were conducted during 1928 at Linden and during 1929 in Ventura County to determine how far walnut pollen may be transported by wind. Pollen grains were collected upon suitably prepared glass plates placed at various distances in open fields to the leeward side of trees shedding pollen. At certain intervals the plates were collected, the grains counted, and the number per square millimeter was ascertained.

The following are averages of the number of pollen grains distributed per square millimeter per day of 24 hours in rather strong wind when the pollen-shedding season was at its height:

Under trees, 8.
At 60 feet away from nearest trees, 4.
At a distance of 150 feet from the nearest trees, 2.9.
At a distance of 250 feet, 1.7.
At a distance of 500 feet, 1.
At a distance of 1,000 feet, 0.3.
At a distance of one half mile, none.

The surface areas of receptive stigmas vary from 10 to 50 square millimeters. Therefore, theoretically, each stigma under favorable wind conditions stands a good chance of receiving a considerable number of pollen grains each day, even at a distance of 1,000 feet, or for a distance equal to 16 or 17 rows of trees as commonly planted in walnut orchards. Figure 14 shows the number of pollen grains a stigma would theoretically receive at the distance and under the conditions described. Beyond a distance of 1,000 feet there is very small chance of stigmas receiving pollen. Furthermore, the trees themselves obstruct air currents to a considerable degree. It is probable that

[10] If placed side by side, it would take 550 Persian walnut pollen grains to cover a distance of 1 inch.

under orchard conditions the actual number of grains reaching the stigmas is considerably less than the number given for the time indicated. Since on an average only 23 percent of the grains were found viable, the number of viable grains reaching the stigmas at the various distances would be approximately one fourth the number indicated. It is probable that the nonviable grains, which are often devoid of protoplasmic contents, being somewhat lighter than the viable ones, would be carried to a greater distance than the viable grains, so that the percentage of viable grains received by the stigma would decrease with the distance.

It is safe to conclude that when the wind is favorable walnut-pollen grains will be carried very effectively across several rows of trees at common planting distances, and it appears that in some cases pollen will be carried across 15 rows or more in sufficient quantity to result in satisfactory pollination. Pollinizers need not constitute a large

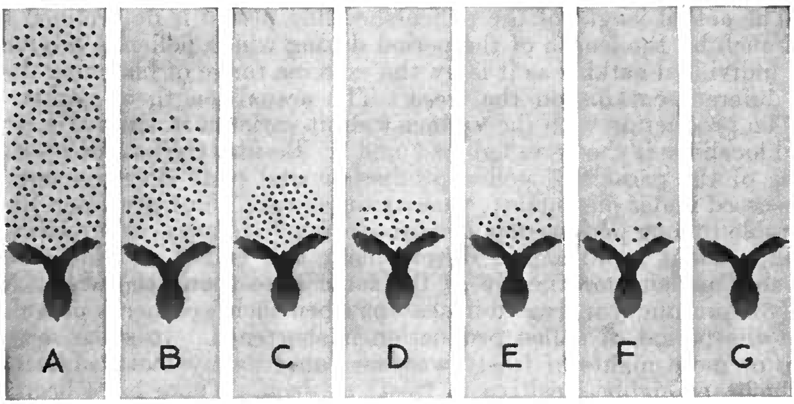

FIGURE 14.—Diagram illustrating the number of pollen grains stigmas of the size indicated would receive in 24 hours under conditions given in the discussion. Each dot represents a pollen grain (the dots are necessarily larger than pollen grains): *A*, Pistil in lower branches of tree would receive 192 pollen grains; *B*, pistil to the leeward 60 feet would receive 96 pollen grains; *C*, pistil 150 feet to the leeward would receive 69 pollen grains; *D*, pistil 250 feet away would receive 30 pollen grains; *E*, pistil 500 feet away would receive 24 pollen grains; *F*, pistil 1,000 feet away would receive 7 pollen grains; *G*, pistil one half mile away would receive no pollen grains.

percentage of the orchard if placed at suitable intervals to the windward side of the trees for which pollination is desired. If 5 percent of the trees in an orchard consist of pollinizers judiciously placed, no tree to be cross-pollinated will be more than three rows away from the source of pollen. Even if the grower desires to keep the varieties in solid rows for convenience in harvesting, the bulk of the orchard can consist of any variety desired. Effective results also may be obtained by grafting over certain branches with a variety suitable as a pollinizer. The chief disadvantage of this method lies in the care and labor required to separate the nuts of the different varieties at harvest time, which must be done unless the pollinizer is such that it produces nuts similar to those borne by the rest of the tree. It is possible that in some of the types being studied for pollinizers the nuts may ripen at a different time from the main crop, and some of the annoyance of separating the nuts may be avoided by harvesting the regular crop and the nuts from the pollinizer trees at different times.

PERIOD OF POLLEN SHEDDING

Since the pistils on a tree do not all develop at the same time, the period during which pollen is shed is very important as affecting the probability of the pistils receiving pollen at the time the stigmas are receptive.

In order to find how long a single catkin produces pollen, a great many individual catkins were tagged and records kept of the dehiscence of the anthers. In cool weather, such as prevailed at Ventura during parts of the blossoming season of the Placentia in 1928, individual catkins produced pollen for as many as 5 or 6 days. During the moderately warm weather which prevailed at Ventura throughout much of the blooming season of 1929 individual catkins seldom produced pollen for longer than 3 days, and most of the pollen was shed in 1 or 2 days. In the interior valleys of California during hot sunny weather individual catkins are often limited in pollen production to 1 day.

The actual length of the pollen-shedding period is determined not so much by the length of the period during which pollen is produced by individual catkins as it is by the extreme range of blooming dates of different catkins on the trees. The actual length of periods of pollen production with the various walnut varieties in various seasons and localities is shown in figures 7 and 8. Besides the lack of overlapping of the periods of pollen production and pistil development, as discussed under dichogamy, various other conditions are often unfavorable to long periods of pollen production. Hot, dry, sunny weather brings about rapid catkin development and causes all the catkins to shed pollen more nearly at the same time than otherwise. Not only is protandry increased in seasons when such weather is prevalent but the period of pollen production is shortened. In some seasons one or more nights of frosty weather cause partly matured catkins (which are highly sensitive to frost) to drop. There have been instances when practically every catkin has been destroyed by frosts, as was the case with the Payne in certain sections during the spring of 1929. Even should some of the later catkins be spared, frost may greatly reduce the period of pollen production. Moderate winds are favorable to pollen distribution, but strong winds tend to loosen well-developed catkins from the tree, causing them to drop. In damp weather molds and other diseases sometimes destroy the flowers in the developing catkins, thus preventing pollen grains from maturing. Even when molds or diseases are not present, rains or fogs destroy pollen grains matured by the catkins. Bees gather great quantities of pollen from the walnut. Other insects, including several types of beetles and flies, feed upon walnut pollen. Such insects, when numerous, consume considerable quantities of pollen.

Collectively these agencies play a more or less important role in reducing the number of pollen grains or in destroying the catkins, thus shortening the period of pollen production and decreasing the probability of pollination taking place, often to such an extent as to affect the commercial crop appreciably.

QUANTITY OF PISTILS PRODUCED

Regardless of how satisfactory all other pollination factors may be, heavy crops of walnuts cannot be produced unless a large number of pistils develop. Some varieties, such as the Payne, are precocious bearers of pistils when young, but tend to produce too few pistils on old trees, and must be pruned to encourage vegetative growth of a type which produces pistillate flowers at the terminals of the shoots. The Franquette and some other varieties produce few pistils when the tree is young and more as the tree gets older. In general, it may be said that the older the tree the larger the number of pistillate flowers. Certain varieties, including the Concord, Eureka, San Jose, Placentia, El Monte, and most trees of the Santa Barbara type tend to produce pistillate flowers in especially large quantities. Counts made upon moderately old trees of the Placentia variety during one season showed 3,000 to 8,000 pistillate flowers per tree. Other factors in addition to age of tree affect the number of pistillate flowers borne. Whenever vegetative growth is not plentiful for any reason, the number of pistillate flowers borne per tree is usually small. Often trees lacking in vigor produce few pistillate flowers. As a general rule, walnut trees over 12 years of age produce enough pistillate flowers to permit of good crops under favorable conditions.

SIZE OF STIGMA MOST SUITABLE FOR POLLINATION

During the progress of the experiments it was found important to ascertain at what stage the stigma of the walnut is most receptive. Pollen was excluded from the pistillate flowers by methods already described (p. 5). At the proper time various stigmas were hand-pollinated, and each one was tagged and recorded according to the following six sizes: (1) Very immature pistils with stigmas showing division, but not having the inner surfaces separated; (2) pistils

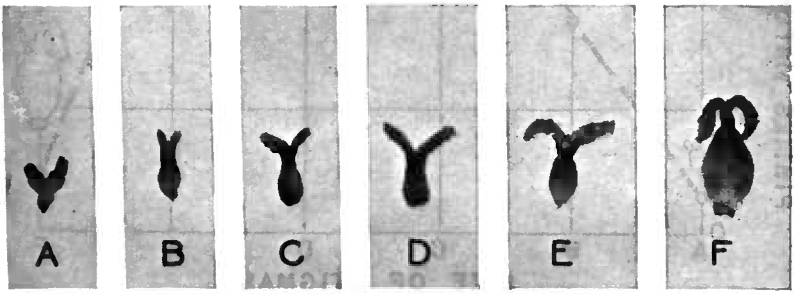

FIGURE 15.—Walnut pistils showing relative receptivity of stigmas: *A*, Very immature stigmas; *B*, small stigmas with inner surfaces visible; *C*, medium-sized pistil with stigmatic surfaces well developed; *D*, large stigmas fully developed; *E*, very mature stigmas just before stigmatic fluid ceases to be produced; *F*, stigmas with glandular surfaces partly dried. Experiments showed that stigmas at the stages indicated by *C* and *D* are in the best condition to receive pollen. The stages represented by *A* and *F* are unsatisfactory for pollination purposes. (See also fig. 16.)

with small stigmas having the inner surfaces visible, but with the rough or papillate surfaces only slightly developed; (3) pistils medium in size with the stigmatic lobes and glandular portion of the surfaces well developed; (4) pistils quite large, with stigmas fully developed in every respect and usually with stigmatic fluids present when pollinated; (5) stigmas very large, just before the stigmatic surfaces begin to dry (at this stage secretions upon the surface are not usually visible); (6) pistils possessing stigmas with the glandular surfaces partly dried. The different sizes are shown in figure 15. After each pollination was made the pistils were again protected in the customary manner from further pollination by natural methods.

No attempt was made to select an equal number of pistils of each of the six sizes. The pistils were taken as they came and the size of each recorded and segregated. In this way all sizes of pistils were recorded on all portions of the tree and upon each branch. The percentage of the matured nuts resulting from each size of the pollinated stigmas was taken for comparison. A summary of the results according to the sizes of the pistils is shown in figure 16.

It will be seen that the highest percentage of nuts resulted from the application of pollen to stigmas of from medium to large size;

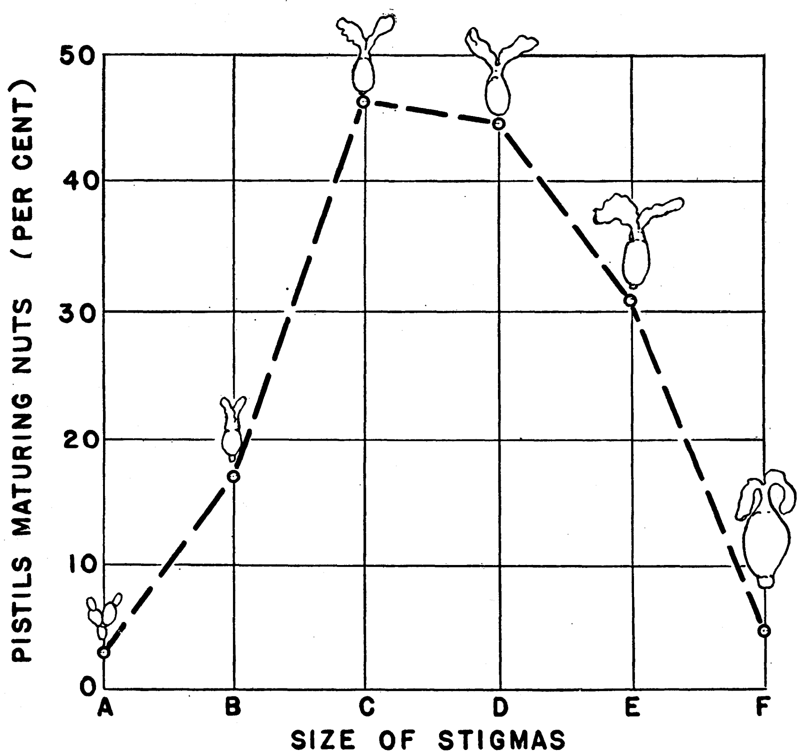

FIGURE 16.—Percentage of pistils maturing nuts as a result of the pollination of stigmas of the sizes shown. The stage of development of the pistils when pollinated is indicated by the letter *A, B, C, D, E,* or *F,* as explained in figure 15, and by the accompanying illustration.

that is, to stigmas mature in all respects and at a time when the stigmatic fluid was being secreted by the glandular portion of the surfaces. Pollen applied to very mature stigmas in which the glandular portions were ceasing to secrete fluid caused a smaller set of nuts than when applied to stigmas somewhat younger. After the glandular portion dries, the application of pollen results in practically no set of nuts. When stigmas more or less immature, as indicated by *A* and *B*, are pollinated the percentage of nuts produced is much lower than when pollen is applied to pistils of the sizes indicated by *C* and *D*. Individual walnut stigmas usually remain receptive for a period of several days, the length of time depending largely upon the weather.

PARTHENOGENESIS

It was found that in some varieties of the Persian walnut a small percentage of the pistils developed into fruit by parthenogenesis, i.e., fruit formed without pollination. The matter will not be fully discussed inasmuch as additional experiments must be conducted before dependable conclusions can be drawn. As yet it is not known what form of parthenogenesis exists in the walnut. In certain experiments both normal and abnormal nuts were produced by parthenogenesis. In some cases the kernels of such nuts were normal in appearance; in others the shells enclosed no kernels or the kernels were imperfectly formed. Figure 17 shows both abnormal and normal nuts produced by parthenogenesis under controlled conditions.

Evidence seems to show that parthenogenetic and parthenocarpic development of walnuts has sometimes taken place to a considerable extent in commercial orchards. In several instances orchards of single varieties (planted in solid blocks) long distances from other varieties have produced some fruit from pistils developing after frosts had destroyed the catkins. A striking illustration of this occurred in 1929, in which freezing weather destroyed all pistils and catkins upon Payne trees. Pistils were produced a second time upon the new growth, following the freeze, but no catkins developed. This second production of pistils was completely destroyed by a second freeze. A third crop of pistils was produced later, and some of these, without any possible chance of having received pollen, developed nuts. The percentage of set was small, but the total number of nuts produced was sufficient to warrant harvesting.

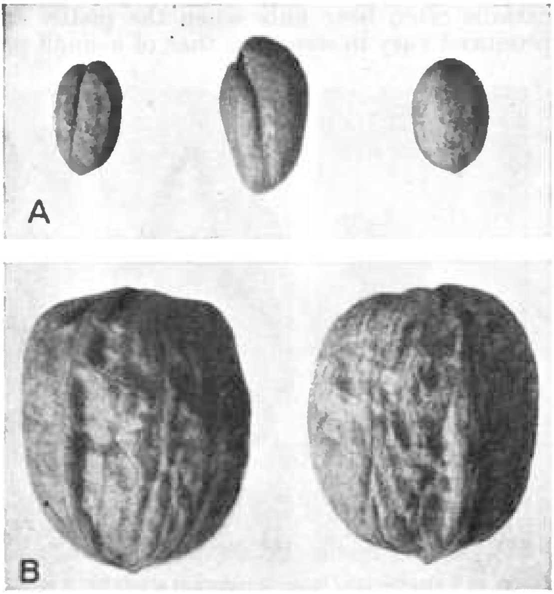

FIGURE 17.—Payne walnuts produced parthenogenetically: *A*, Abnormal nuts; *B*, normal nuts.

ABNORMAL NUTS

Abnormal nuts are often produced in sufficient quantity to be detrimental to the commercial crop. Some of these abnormalities are, no doubt, due to conditions independent of pollination, but it appears that some of them may be due to secondary effects of pollination. Further experiments will be necessary before it can be definitely stated what the secondary effects of pollen are upon the shape of the nut, the smoothness and quality of the shell, the peculiarities of kernel development, and the types of the sutures and partitions. With the exception of a small amount of work done during a single season, the only data available on this matter were collected under field conditions in which a variety was likely to receive different varieties of pollen in different portions of the orchard.

Occasional variations and abnormalities occur in the inflorescence of the walnut. A striking abnormality is shown in figure 18. It will be noticed that here the catkins have become greatly modified. Certain portions of the catkins instead of developing staminate flowers produced pistils. Many times these freak catkins develop abnormally shaped pistils. At other times they bear normal pistils. They may also bear both stamens and pistils, as shown in figure 18, *A* and *C*. Modified catkins of these types have been found varying in length from an inch to over a foot. The abnormal or modified catkins often bear nuts when the pistils are pollinated. The nuts produced vary in size from that of a small pea to an inch or more in

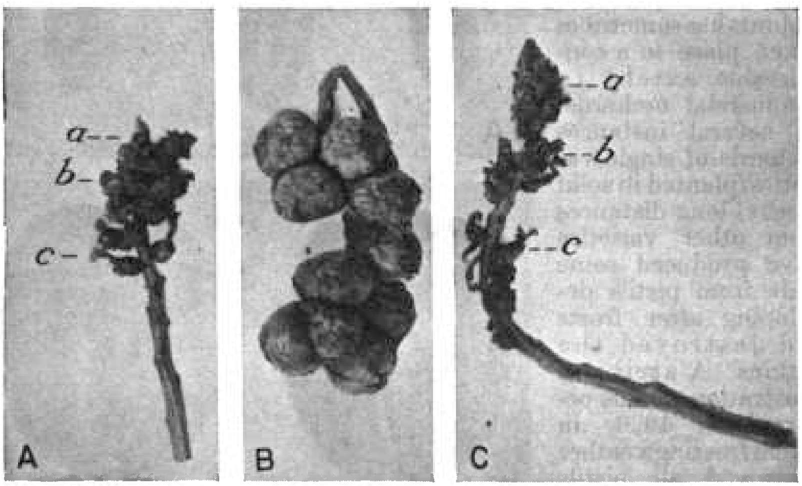

FIGURE 18.—Abnormalities in the development of catkins, *A* and *C* showing modification of flowers to a varying extent proceeding from the tip upward. At *a* is a mass of stamens of abnormal sizes and shapes. At *b*, instead of staminate blossoms, there are imperfectly formed pistils, and at *c* are perfect pistils. *B*, Nuts set as a result of pollination of the pistils of an abnormal catkin. The nutlets shown in the illustration were about three fourths inch in diameter and were perfect in every way, including hull, shell, and kernels.

diameter. Often such nuts borne upon the axis of the modified catkin are uniform in size and may or may not be normal. The nutlets shown in figure 18, *B*, were about three fourths inch in diameter and were perfect in every way.

LIST OF VARIETIES

Because there is much confusion regarding the names of certain of the walnut varieties grown in California, the following brief statements are made relative to varieties mentioned in this bulletin:

Concord.—About 1890, Felix Gillet, of Nevada City, Calif., distributed some seedling trees which he had originated. Smith (*10*) states that one of these trees planted on the ranch of George Westcott in Concord served as the original source of bud wood of the Concord variety. Many of the native black walnut trees in Contra Costa County were grafted to this variety, which received its name from the locality in which it was first grown extensively. According to

Wickson (*14*), Leonard Coates began to distribute trees of the variety from his nursery in 1908. It has been widely distributed throughout northern and central California.

Ehrhardt.—The Ehrhard tvariety originated from a Santa Barbara seedling. Trees of the variety were first grown in quantity by V. E. Ehrhardt, of Santa Ana. It is now widely distributed, especially in southern California. The acreage at present is not large.

El Monte.—A Santa Barbara seedling tree on the Richards place near El Monte, Calif., was found to possess certain desirable qualities and to differ somewhat from the typical Santa Barbara trees. Trees propagated from this seedling were distributed to a considerable extent in southern California, and the variety was named El Monte from the locality in which it originated. Mr. Richards took the variety to Fallon, Calif., and from there it was distributed to the Modesto district and to various other points in northern and central California by J. A. Cover. While the total acreage of this variety is not large when compared with that of the leading varieties, it is widely distributed and the total yield amounts to a considerable tonnage.

Eureka.—The Eureka variety originated as a seedling tree at Fullerton, Calif. It is widely distributed throughout the State and has been especially popular in the interior valleys.

Franquette.—The Franquette variety originated in France. According to the records of Felix Gillet, he introduced the variety in California as early as 1871. The Emily Vrooman orchard at Santa Rosa was probably the first in which the variety was grown on a commercial scale. From the Vrooman ranch it was distributed throughout the State. It appears, however, that other varieties of walnuts were introduced from France and were planted by growers who believed they were getting the true Franquette. It also seems that some California seedlings were erroneously thought to be Franquette. Scions from such seedlings were distributed to various orchards. These facts, no doubt, account for some of the variations in the so-called Franquette types. However, most of the Franquette orchards in California consist of trees true to the variety, and they are often called "Vrooman Franquette." It is this variety to which the name "Franquette" is applied in this bulletin.

Frostfighter.—The Frostfighter is a hybrid nut originated and named by Frank Leib, of San Jose. Although the nut is of no value commercially, the tree appears to be of considerable promise for pollinating the Franquette and other late-blooming varieties. From a few years' observation in the San Jose district, it has been found that the blooming period of the catkins extends over a long time, covering the entire period of pistillate bloom of the Franquette. Pollen is produced in abundance. The nuts appear to ripen somewhat later than those of the Franquette, which helps to prevent their being mixed during harvesting.

Golden Nugget.—The Golden Nugget variety originated from heavy-bearing Santa Barbara trees grown on the Charles Sanderson ranch at Whittier. J. A. Cover introduced the variety to central California, propagating and testing it on his ranches at Modesto. The variety is not extensively planted.

Grove.—The original tree of the Grove variety was a seedling growing at the L. E. Grove home in the Santa Clara Valley. Exclusive right to propagate the variety was purchased by W. C. Anderson about 1912. The variety was first grown extensively in the Anderson orchards at Linden and has been planted elsewhere in the district. It is a comparatively new variety and has not been tested thoroughly in all the walnut districts in California.

Hinds.—The name Hinds is given to the northern California black walnut (*Juglans hindsi*) by the American Joint Committee on Horticultural Nomenclature (*3*).

Kaghazi (*Persian*).—In addition to being used as the generic name for all varieties of *Juglans regia*, the name Persian is applied in California to the Kaghazi variety. There is some doubt as to its exact origin. In an anonymous article in the Pacific Rural Press (*1*) the following statements are made: "* * * the late James Shinn, of Niles, secured in some way a nut from the real home of *Juglans regia* in Persia, and he called it the 'Persian walnut,' using also a species name which was in some way connected with it, to wit, 'Kaghazi.' * * * The late Mr. Shinn was not the only distributor of the Kaghazi. * * * W. P. Hammon * * * took a hand in distributing it when he was a nurseryman in the eighties. The nut was also sent out as a complimentary premium to subscribers of the San Francisco Bulletin under the direction of Mr. G. P. Rixford, and of these Mr. Hildebrand received two, from one of which grew the splendid tree shown in the picture on this page." The photograph referred to was sent to the Pacific Rural Press by D. W. Miller, of Linden, and shows the large Persian tree growing on the old Hildebrand place, a few miles above Linden, on the south fork of the Calaveras River.

E. R. Lake (*8, p. 44*) states: "Nuts obtained through the American consul in Persia were planted by Mr. Meek, of Hayward, Cal., and from these were produced two trees, the nuts of which were deemed especially meritorious. To these trees was given the name Kaghazi." Lake mentions further Kaghazi trees grown near Goleta.

Ralph E. Smith, in discussing the variety, states that "it is a fairly distinct variety", and substantiates the opinion that it was introduced by William Meek.

It seems apparent that the variety originated on the Meek ranch at Hayward and was obtained from there by James Shinn, who, among others, distributed it extensively. Much confusion probably arose through the seedling trees resulting from the planting of nuts from Kaghazi trees. At any rate, at one time the variety was widely distributed over California, and it is still found in many sections.

Lucretia.—The Lucretia variety was originated by L. E. Grove and is of interest because of its apparent suitability as a pollinizer for the Payne and other early-blooming varieties. The nut seems to be of rather good quality, but is said by some to be subject to molding in certain California climates. The variety is comparatively new and as yet has not been tested extensively. The first commercial planting was made in the Anderson and in the Miller orchards at Linden. It has been distributed to a large number of the California walnut-growing districts for trial, but it will be several years before it can be stated whether the variety is commercially suitable or not for the various localities.

Mayette (Grenoble).—Early in the history of walnut development in California Mayette trees or scions were imported from France by Felix Gillet, of Nevada City, by Judge S. F. Leib, of San Jose, and probably by John Rock, of Niles, and others. Many growers in California planted Mayette trees originating from these sources. Tribble Bros., of Elk Grove; G. P. Rixfora, of San Francisco; and, to a less extent, A. T. Hatch, of Suisun City, were among the early distributors of Mayette trees. Eventually it became customary in California to apply the term "Mayette" to any seedling tree producing nuts of an oblong, round, or ovate shape even remotely resembling the Mayette. Furthermore, the name was used with descriptive terms to designate various types of seedlings. As time went on there came to be much confusion as to what constituted the Mayette walnut. The loose use of the term has continued until the name Mayette is used to designate any type of nut which can be disposed of in the markets under that name. According to Felix Gillet, the terms Mayette and Grenoble are synonymous. In this bulletin the term Mayette is used to designate the late-blooming Mayette or Grenoble variety, and Early Blooming Mayette is applied to a strain of Mayette originally introduced from France producing nuts resembling the true Mayette in character but possessing a different blooming habit. All other types resembling the Mayette have been eliminated from the experiments as soon as discovered and are not mentioned in this bulletin.

XXX Mayette.—The "triple X" Mayette is a seedling that originally came from Felix Gillet, of Nevada City. J. A. Cover obtained scion wood of the variety from the Morrow ranch in the Santa Clara Valley. Mr. Cover named the nut "XXX Mayette" and propagated it on his ranch near Modesto. Because the nuts were apparently resistant to sunburn and possessed attractive light-colored kernels Mr. Cover distributed the variety to various places in central California, where it is now grown on a commercial scale. Smaller plantings and occasional trees of the variety are scattered throughout the State. Mr. Cover states that trees of this variety do not average as heavy crops as is the case in some of the other heavy-bearing varieties.

Meylan.—This variety was introduced into California by Felix Gillet, of Nevada City. Although the nut is of excellent quality, few extensive commercial orchards of the variety are in existence in California. This is doubtless due to its light bearing habit. The variety has been widely scattered over California, and a few trees here and there can be located in each walnut-growing section.

Parisienne.—The Parisienne variety was first introduced into California from southeastern France by Felix Gillet, of Nevada City. Later John Rock, G. H. Kerr (*11*), and others seem to have imported the variety. One of the first commercial plantings of Parisienne trees was made by A. T. Hatch, of Suisun City, on one of his ranches in northern California. Some of these original trees are still standing at East Biggs. A considerable number of trees of the variety can be found in various parts of California.

Payne.—The Payne variety originated from a seedling tree grown upon the Payne ranch, near Campbell, Calif. George P. Payne brought the variety into bearing on a commercial scale in his own orchard. It has been distributed to practically all the walnut-growing districts in California, but the largest commercial plantings of the variety are found in central and northern California.

Placentia (*Placentia Perfection*).—The Placentia variety originated at Placentia, Calif. It is one of the most extensively grown and commercially important varieties in southern California and has been tested in practically every walnut district in the State. The Placentia nuts constitute the bulk of those sold in the market under the term "budded". There are several types of walnuts called Placentia. L. D. Batchelor (*4*) calls attention to four of these types. If the blossoms and characteristics of the foliage are taken into account, as well as the characteristics of the nut, it appears that there may be even more types of seedlings known as Placentia. One of these types, however, constitutes most of the acreage in California, and it is to this "strain" that the name Placentia is here given.

Praeparturiens (*Fertile*).—According to Felix Gillet, the Praeparturiens variety originated in France in 1828. He introduced it into California during 1870 and 1871. At one time it was grown extensively in central and northern California. It is also found to a less extent in other walnut-growing sections of the State. Mr. Gillet propagated seedlings of second and third generations of this variety, and these were distributed to various sections of California. Mr. Gillet held the opinion that the second-generation seedling trees were superior to the original Praeparturiens. The data given in this bulletin apply to the original Praeparturiens and not to the seedlings.

Pride of Ventura.—The Pride of Ventura variety is entirely different from the Pride of Oregon, though both are often referred to as "Pride." The Pride of Ventura originated as a seedling tree in a grove of Santa Barbara trees on the ranch of E. O. Tucker, near Ventura, Calif. It is not to be confused with Tucker's Pride, of which there are a few trees in northern California. Pride of Ventura has been planted commercially to a limited extent, mainly in Ventura County.

San Jose (*San Jose Mayette, Wiltz,* and *Wiltz Mayette*).—Felix Gillet, of Nevada City, Calif., planted seeds from the Mayette trees he had imported from France. Out of the first seedlings resulting he selected several of the better ones. From one of these R. Wiltz, of San Jose, established a commercial orchard and was responsible for introducing the variety, which was called San Jose, San Jose Mayette, Wiltz, or Wiltz Mayette. The name by which the variety is known depends somewhat on the district in which it is grown. Although grown mainly in the Santa Clara Valley and in central California, occasional smaller plantings are found in various other California localities. The San Jose is distinct from the Mayette or Grenoble variety, but is sometimes confused with the various Mayette types.

Santa Barbara (*Santa Barbara Soft Shell*).—The Santa Barbara trees, grown so extensively in southern California, originated as selected seedlings from the ranch of Joseph Sexton at Goleta. Practically all the early plantings in southern California consisted of trees originating in this manner. Although the types of trees vary to some extent, it is rather remarkable how similar in appearance the nuts were from the early plantings. There is now much variation in the seedling trees. The widest variation appears to occur in seedlings planted since the Sextons distributed trees. In this bulletin the data are confined to typical trees that originated from the Sexton ranch, so far as can be determined.

Santa Rosa.—Luther Burbank originated a seedling tree and distributed it under the name Santa Rosa. According to Wickson (*14*) the name was also applied to several inferior seedlings. At present it appears that most trees called by the name Santa Rosa are the same as the original in quality of nut and blooming habit.

Wasson.—The Wasson variety originated from a seedling Santa Barbara tree near Saticoy. The original tree is still standing. The variety was first distributed in Ventura County. Most of the Wasson trees are found in southern California.

Willson (*Willson Wonder*).—There is much confusion in regard to trees of the Bijou type found in California under the names Acme, Alpine, Bijou, Calavette, Gant, Gibbons, Jauge, Klondike, Mammoth, Payou, and Willson. In this bulletin a grouping under two divisions has been followed, the rather late-blooming types being called "Willson" and the early bloomers being listed as "Bijou." Much study is necessary before trees of this type in different orchards can be placed under the correct variety names with certainty.

SUMMARY

All walnut varieties tested were found to be self-fertile and interfertile and capable of setting a satisfactory crop of nuts either with their own pollen or with that of other varieties, provided pollen was available when the stigmas were receptive. Certain combinations appeared to give especially high percentages of set, but in all cases tested the results suggest that the varieties will give satisfactory commercial crops whether selfed or crossed in any combination if other conditions are favorable for pollination and crop production. No advantage was apparent in cross-pollination over self-pollination, though further study should be made of the quality of nuts produced.

The 17 varieties of Persian walnut studied were all found to have dichogamous tendencies. Of these, 13 were found to be practically or completely dichogamous in some seasons and places; self-pollination therefore could not take place. In 78 out of 200 averages for given varieties, districts, and seasons, cross-pollination appeared necessary for maximum set.

Some varieties tend to be protandrous; others to be protogynous. They differ from one another in the degree of protandry or protogyny to which they are subject under given conditions. Young trees of all varieties whether protandrous or protogynous in tendency are much more subject to dichogamy than are old trees. While the dichogamous tendency decreases with age, it does not disappear even in very old trees.

The varieties are consistent in relative time of bloom under the same conditions. This permits classification roughly into early, intermediate, and late varieties. The varieties in each group do not bloom at exactly the same time except in seasons which tend to crowd the bloom together.

The exact dates of bloom, length of blooming period, and blooming habit (in regard to dichogamy) are affected greatly by variations in the seasons. The dates on which a variety may begin to bloom in a given district vary by a month or more. The length of the blooming period may vary from a few days to 2½ months. A warm sunny spell occurring immediately preceding or during the normal blooming period of a variety will start the bloom. The rapidity and length of blooming period will depend on the degree and duration of the warm weather.

In coastal climates, where the winters are mild and there is little contrast between winter and spring, and where fogs and cloudy weather are prevalent, a relatively late and long period of blooming is common. In the interior valleys, where the winters are colder, the springs warmer and sunnier, the varieties tend to bloom earlier, develop more rapidly, and bloom for a shorter period. Some of the late-blooming varieties cannot be grown satisfactorily in the southern coastal districts because they bloom too late for the nuts to mature. Other varieties may bloom so early in the interior valleys that they often suffer from frost injury. The late varieties bloom in the interior at about the time the early varieties are blooming in the southern coastal section. In intermediate districts the date and length of bloom are affected correspondingly. In general, the tendency of the coastal climate is to increase protogyny and modify protandry, while an interior climate tends to increase protandry and to modify protogyny.

The climate, season, and weather influence greatly the degree and character of dichogamy. A variety normally protandrous may become protogynous under particular climatic conditions, and vice versa.

A long period of bloom, or even a long period of overlapping bloom of pistils and catkins, is not necessarily advantageous for self-pollination, since the conditions that cause a long blooming period may prevent pollination from taking place.

Cross-pollination may be provided for by combining the proper varieties in the planting. Almost any combination of varieties is likely to increase pollination to some extent. It is not possible as yet to recommend for every locality combinations that can be depended upon to give perfect pollination every year, but the grower should be able to select varieties that will improve his chances greatly for securing adequate pollination. Charts (figs. 7 and 8) are the best guide to the behavior of varieties in the districts mentioned. Protandrous and protogynous varieties blooming at about the same time may well be planted together.

Early-blooming varieties planted together will have a longer period of effective pollination than will any one variety in the group. Such interplanting is helpful, though not entirely satisfactory in all respects. The latest blooming variety in the group may go unpollinated if that variety is protandrous, or the earliest may do so if that variety is protogynous.

Late-blooming varieties also help each other to some extent when planted together. They frequently suffer from the same pollination troubles at the same time, and the latest variety in the group, especially if protandrous, is likely to be pollinated inadequately because many of its pistils may come out after the pollen from all the varieties has been shed.

Late and early varieties planted together may help each other in unusual seasons when the blooming of all the varieties is crowded together, but commonly their blooming periods do not overlap. For this reason the combination of late and early varieties is not recommended unless intermediate blooming varieties are planted with them.

The best groupings combine intermediate and early varieties, or intermediate and late varieties, or all three. With these combinations the latest bloomer, if protandrous, is likely to suffer and should not be planted in large quantity, especially in districts where a natural tendency to protandry is likely to be accentuated by the climate.

Great variation was found in the viability of walnut pollens. The percentage of viability of the specimens tested ranged from 0 to 80 percent, the average being 23 percent. When exposed to the air under conditions similar to those in the field, pollen grains deteriorated rapidly. For this reason, pollen remaining upon the branches or foliage cannot be considered important in the commercial production of nuts.

For satisfactory production an abundance of pollen is required. Vast quantities of pollen are frequently produced by the walnut, but its viability is often low. Many of the catkins may be destroyed by frost, rain, fog, insects, or diseases, and there is great waste of pollen in distribution. Young trees tend to produce fewer catkins than do old ones. Certain varieties, however, produce few catkins at any age.

Tests to establish the distance pollen is carried by the wind indicate that in favorable weather it will be carried effectively through at least several rows of trees.

Experiments show that the greatest receptivity in the development of the stigmas occurs when the stigmatic fluids are being secreted most actively.

Parthenogenesis sometimes occurs in the walnut. In certain varieties a small percentage of the pistils has been found to mature nuts without pollination.

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